NEW SOUTH WALES.

DEPARTMENT OF AGRICULTURE, SYDNEY.

PLANT DISEASES AND THEIR REMEDIES,

BY

N. A. COBB, B.Sc., PH.D.

(Pathologist to the Department of Agriculture, New South Wales).

DISEASES OF THE SUGAR-CANE.

WITH OVER SEVENTY ILLUSTRATIONS.

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DISEASES OF THE SUGAR-CANE.

(*With over seventy illustrations.*)

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To Mr. Edward Knox, General Manager of the Colonial Sugar Refining Company, for introductions to the officers of the Company at Harwood, and for numerous specimens of cane from various parts of New South Wales, Queensland, and Fiji; also for the loan of Fig. 14.

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Figs. 5, 9, 10, 11, 32 and 33, were drawn by Mr. E. M. Grosse; fig. 1 by Mr. F. C. Wills; the remainder by the author.

I. Microbe Diseases of the Sugar-cane.

Gumming of Cane.

(*Bacillus vascularum.*)

Before attempting to describe the disease to which I give the name *Gumming of the Sugar-cane*, it will be advisable to glance at the structure of the cane plant.

Sugar-cane is a gigantic grass, having a solid stem. From place to place on its stalk occur joints or nodes, and from these nodes the leaves grow. If the leaves be stripped in succession from one-year-old cane, the spaces between the joints or nodes (internodes as they are called) are seen to

grow shorter and shorter, as leaf after leaf is removed, until at last the distance from one joint to the next does not exceed a quarter of an inch. At this point the leaves will be found to be no longer green but white, and to be wrapped snugly together in a long and very slender cone, as shown in Fig. 1. When the cane plant is becoming mature this cone contains the inflorescence. At maturity the inflorescence takes the form of a panicle or plume, and produces seed like many other grasses, only, of course, on a larger scale. Cane-growers apply the term *arrow* to the inflorescence of cane. This term is used both to designate the flower after it has appeared and the long white cone mentioned above. Thus they say "the cane has arrowed," meaning it has flowered; or "the frost has injured the arrow," meaning the frost has injured the growing point of the cane, regardless of whether the inflorescence is yet formed or not. Similarly they speak of "a borer getting into the base of the arrow," meaning into that part of the stalk of the cane where the internodes are very short, *i.e.*, near the top of the stalk, say at A, Fig. 1. They say this whether there is any embryo of the future flower already formed or not. Both these ways of using the word "arrow" are proper enough, but one should be careful to make it clear in which sense the word is used.

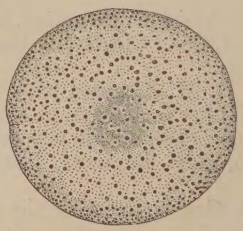


Fig. 2.—Thin slice across healthy cane, natural size, as seen against the sky, and showing cross-sections of the fibres as dark spots.

To understand the internal structure of the cane plant it is necessary to cut up the plant in various ways. Cut squarely across a stalk of cane, and, having made a smooth surface, remove as thin a slice as possible. Hold this slice up to the light and it will appear as in Fig. 2. As seen against a strong light the slice appears spotted, the number of spots varying from 1,000 to 2,000. These spots are larger near the centre of the slice, but small and very close together near the margin. Any one with good eye-

Fig. 1.—Top of a stalk of cane with the leaves nearly all stripped away; A, top of the stalk; B, base of the arrow; C, the arrow, or rather the topmost leaves, closely wrapped into a very narrow cone, which contains the embryo of the arrow. The cavity containing offensive matter, to be spoken of later on, is located between A and B.

sight looking at one of the larger spots attentively will be able to see that it is pierced by at least two holes. To see these holes it is absolutely necessary to hold the slice squarely in front of the eye, for if it is tipped ever so slightly the holes will not be seen. This is because the holes run squarely through the slice, lengthwise the cane—or what was the cane. These points are more clearly and readily seen with the aid of a magnifying glass.

Take now a piece of rotten cane, such a piece as has been exposed to the weather for many months. It breaks open easily. Much of the tissue is rotted away and gone, but the fibres remain. One sees immediately that the spots observed in the slice of cane, shown on Fig. 2, and of which we have just been speaking, are the cross-sections of fibres.

Let us now put two and two together.—There were two holes in each spot, therefore, there are two holes or tubes running through each fibre.

The fibres of the cane, where do they go? How are they distributed? To answer these questions it is only necessary to refer to our piece of rotten cane. When split, it shows that the fibres pass through the joints or nodes into the next internode, but that at each joint they give off branches at right angles.

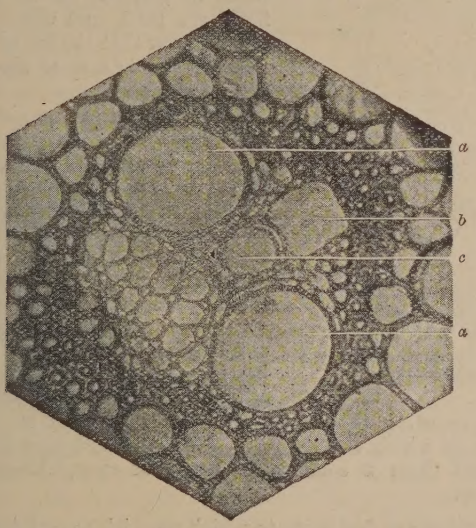


Fig. 3.—Cross-section of a fibre of sugar-cane as seen under a powerful microscope. *a*, *a*, the two large sap-vessels; *b* and *c*, two annular vessels, a portion of one of the annules or rings shows in *c*, but that in *b* has been torn away.

Whither do the branches go? It does not take long to find out. The branches seem to be inextricably tangled together at the joint, and this is the reason that the joints of a cane-stalk is so solid; but it will be discovered that the branches go to one of four places—

1. They go to the leaf belonging to the same joint, or
2. They go to the bud belonging to the same joint, or
3. They go to a root springing from the same joint, or
4. They join another fibre, or branch of a fibre.

The cane-plant, then, is traversed by a system of fibres, which give off branches to the leaves, buds, and roots. But how about those two tubes in every fibre? Is it not as plain as daylight that the cane-plant has a system of tubes or vessels running to all parts?

It is through these vessels that the sap circulates. Water taken from the ground is sent upward through them as sap to supply the leaves. The leaves having formed out of the sap and air organic substances, send them forthwith back through these vessels down to nourish the stalk. How important these vessels must be to the plant! As important as his veins to an animal!

Not content with this superficial knowledge of the sap-vessels, let us examine them more carefully. A very thin slice across healthy cane shows us that the fibres have a very complicated structure, as is shown in the preceding page, where the two larger sap-vessels are shown to be accompanied by other smaller vessels, called annular vessels.

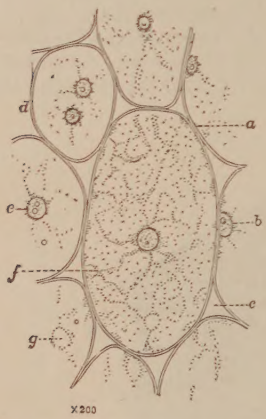


Fig. 4.—A few cells from the sugar-bearing tissue of a healthy seedling cane. *a*, cell-wall; *b*, nucleus; *c*, intercellular space containing air; *d*, a cell containing two nuclei; *e*, a nucleus containing two nucleoli; *f*, protoplasmic network.

The walls of the sap-vessels, as well as those of most of the other cells in the fibre, are thick and woody, and it is on this account that the fibres are so strong, and withstand decay so much longer than the softer tissues.

Turning now to the tissue composing the remainder of the cane-stalk we find it to be composed of thin-walled cells as shown in Fig. 4. This figure was prepared from a view through the microscope of a very thin slice of the white tissue surrounding the fibres. It was taken from a perfectly healthy seedling cane, and was sketched within ten minutes after the cane was harvested. As soon as the slice was cut, it was mounted in an imitation cane juice, and drawn immediately; therefore, reliance may be placed on the figure as accurately representing the natural living condition of the cells. These cells are those in which the sugar is contained, and they form, therefore, when considered from a commercial point of view, the most important part of the cane.

In each cell there are five parts to which we wish to call attention:—

1. *The cell wall.*
2. *The nucleus.*
3. *The nucleolus.*
4. *The network of granular protoplasm.*
5. *The spaces among the meshes of the protoplasmic network.*

1. Each cell has a wall which divides it from every other cell, and from the surrounding air, for it must be understood that among the cells, of which plants are composed, air always exists, and is essential. The cell wall is thin, and is composed of cellulose, a substance closely resembling the commercial article known as celluloid.

2. Each cell contains a nucleus, the head centre of its activity. The nucleus is commonly located near the centre of the cell, but may occur near the wall. When a cell is about to divide and become two cells, the nucleus first splits in two, and the division into two cells soon follows. A nucleus already so divided is shown at *d*. In a short time cell *d* would have become two cells.

3. Each nucleus contains a smaller nucleus called the nucleolus.

4. Radiating from the nucleus in an irregular manner is seen granular matter which forms a perfect network through the cell, and also lines the wall of the cell. This granular matter is known as protoplasm, and is beyond question the most wonderful and important substance known. It is the seat of life, and presents ceaseless activity, its particles for ever moving from place to place. If one of the threads of protoplasm be examined with the aid of a powerful microscope, the particles shown in the figure may be seen to move along the thread in one direction or the other. All parts of the protoplasm move, but the motion is most plainly indicated by the granules, just as floating chips indicate the motion of a quiet stream of water, or a straw shows how the wind blows. We call particular attention to these particles, because we have to mention them again in our description of the microbes found in gummed cane, the resemblance between the two being so great as to easily give rise to mistakes if the observer is not careful.

5. Finally, we have to notice that the spaces of the protoplasmic network are filled with cell-sap, containing cane sugar in solution.

The Symptoms of Gumming.

When a cane crop is gummed it presents a variety of symptoms that vary according to the severity of the disease. When only slightly gummed the crop appears to be in fair condition. Here and there, however, will be seen stools containing one or more stalks with dead tops. The base of the arrow in such cases will be found to be rotten, and usually one or more cavities of considerable size are to be seen near the top of the stalk, filled, or partially filled, with offensive matter. At first one is inclined to attribute these cavities to the inroads of grubs or borers. This idea is soon seen to be mistaken, for there is no entrance or outlet to the cavity, nor are there any traces of excrement, both which facts prove conclusively that the cause lies in some other direction. The tissue about these cavities is generally brown, black, or dark red in colour, and reeking with a slimy, offensive substance, which varies from nearly colorless, through yellow, to brown. Plants whose tops have died from gumming often shoot from buds half way down, but this symptom is not peculiar to gumming. It occurs also in plants nipped by frost or by borers.

If a stalk which has died at the top in the manner described be cut into pieces with a very sharp knife, in such a manner as to leave the cut surface quite smooth, a honey-coloured gummy matter will, in a few minutes, be seen to ooze slowly out and form in droplets on the ends of the cut fibres. This gum is sometimes nearly transparent, sometimes rather opaque, and varies also in colour from nearly colourless into various tints of yellow, according to the stage reached by the disease. This gummy matter is usually more abundant near the top of the stalk than near the bottom, or at least oozes

out more freely. In the course of an hour or thereabouts these droplets of gum become so large as to run together and form large drops, and if two or

Fig. 5.—Stool of gummed cane. *a*, *a*, *a* are diseased stalks, the dry dead leaves of which are shown at *b*, *b*, *b*, *b*. Inside the top of the stalk at *c* will be found the cavity containing offensive matter mentioned in the text.

three dozen cuttings from badly-diseased stalks be laid in a closely-covered box over night one may in the morning collect from their ends a teaspoonful of yellow mucilagenous gum.

The gum which thus oozes out in such quantities, if allowed to do so, at last becomes dry, owing to the evaporation of its water. In this state it appears as bright yellow stains on the end of the cutting. Sometimes the gum oozes out in a state so nearly dry that it hardens as it issues from the fibres into a yellow, coiled-up, hair-like body, and inasmuch as each fibre gives rise to one such body, all the fibres together originate a yellow, mossy appearance on the end of the cutting.

If another stalk, which is apparently sound, be taken from a stool, in which one or more stalks have been already blighted by gumming, as above described, such stalk will be found to exhibit the same symptoms, except that the cavities and rottenness at the base of the arrow are wanting. Moreover, if other stalks be removed from stools of cane standing near by in the same field, but which, as yet, show no outward symptoms of this disease, the chances are that some of them will also be found to be more or less gummed.

In some cases the amount of gum is so small as to ooze out in but a trifling quantity, to be detected only with a magnifying glass. Finally, the quantity of gum may be so small as not to ooze out at all; in such cases a good microscope is necessary to demonstrate that the gum is present.

Fig. 6.—Cutting from gummed cane. The gum has oozed out and formed into drops on the surface of the cutting.

Although I have applied the name of gum to this yellow substance, I do not mean thereby to imply that it belongs to the class of substances by chemists named gums. It does not belong to that class, as will be explained later on. Gumming, however, is a word so descriptive of the main symptom of the disease, and one that appeals so strongly to the common sense as being short, plain, and adaptable, that in spite of a possible objection which might be raised on the ground that the matter from which the name is derived is chemically speaking, not a gum, I have decided to adopt it.

After the cane is cut and ready for the mill gummed stalks can be recognised, not only by the yellow dried-up gum that exists on the cut ends, but also by their colour. Gummed stalks generally have an over-ripe appearance. Green and yellow canes, when badly gummed, become yellowish or orange, or even somewhat purple in colour. The ribbon canes show similar alterations in their yellow stripes, while their purple or black stripes tend to take on a reddish cast. The waxy bloom, usually to be seen on perfectly sound cane has disappeared on badly gummed cane. All the symptoms of gumming seem to be more pronounced when they occur in plant cane than when they occur in ratoons. An explanation of this fact will be offered later on.

In the sugar-mill the juice of gummed cane may be recognised by the greater amount of lime required for its clarification, and there seems to be reason to suppose that the crystallisation of the jellies is slower and less

perfect when they are derived from gummed cane. The sieves used to separate the fibre from the juice are apt to clog up when gummed cane is being crushed. They are easily cleaned with soda.

The foregoing symptoms are those connected with cane so attacked as to produce a marketable crop. In some cases, however, the gumming prevents the growth of the sets. The plants may reach a height of a foot or two feet, but they then die back and shoot again from the base, or from buds half way down the stalk. In such a case the loss is total or nearly so. The gum presents the same features in this case as in milder ones.

Microscopic Features of Gumming.

A microscopic examination of a thin slice across a gummed cane shows at once that the disease is not general, but local. The gum, except in certain cases, is confined to the fibres; in fact, to the sap-vessels, these latter being

Fig. 7.—Thin slice across badly gummed cane, as seen under the microscope—magnified fifty diameters; *a*, a fibre, one of whose sap-vessels is plugged up with gum; *b*, microbes growing outside the fibres; *c*, filaments of a fungus attacking the same tissues; *d*, a comparatively healthy fibre whose two sap-vessels remain as yet free from gum.

plugged up with gum. A cross-section of a healthy fibre shows the sap-vessels as empty spaces, the sap having flowed out in the process of cutting the section; a cross-section of a gummed cane on the other hand shows the sap-vessels to be filled with yellow granular matter, in other words, gum. This confinement of the gum to the sap-vessels is one of the most striking

microscopic features of gummed cane. In advanced cases, and in the more tender tissues at the top of the cane, the gum is not so local in its distribution ; it may, under such circumstances, be found outside the fibres.

Lenses of high power show the gum to be swarming with microbes of the form known as bacilli. When the gum is fresh and yellow in appearance, the microbes are all of one kind whose features are well shown in the illustrations, Figs. 9, 10, and 11 on the following page. This microbe appears to be one not hitherto described, and I propose to call it *bacillus vascularum*, in consequence of its occurrence in the *vessels* of the sugar-cane. Each microbe has about it a small amount of gummy matter, which is a product of its growth. The gum described above as issuing from the sap-vessels of the cane has, therefore, two component parts, namely, microbes and a viscous gummy matter. This gummy matter appears to be a new substance, and to it I have applied the name of *vasculin*. The chemical properties of vasculin will be given later on.

Fig. 8.—View of part of the slice shown in the preceding figure, but more highly magnified; *a*, fungus filaments; *b*, also fungus filaments; *c*, masses of microbes; *d*, masses of microbes growing in a radiating manner owing to the fact that the *bacilli* adhere together in chains.

At last we have arrived at the important question "What are the relations between these microbes and the disease here called gumming?" This question is simple, but its answer is necessarily complicated. What we wish mainly to know is whether the microbes are the cause of the disease. As a result

of hundreds of careful examinations, I am able to say that the disease gumming, as described, never occurs without the yellow gummy matter in the sap-vessels.

The result of even a much greater number of examinations made with equal care showed that the yellow gummy matter never occurred without the microbes, indeed it is very evident that the gum is a product of the growth of the microbes. This leads to the conclusion that the disease never occurs without the microbes being present, and it may be added that many cases were examined in which, in spite of long and careful search, none but the merest traces of other foreign organisms could be found. This is very

Fig. 9.—*Bacillus vascularum* from sugar-cane, stained with methyl violet without heat, and mounted in water.

Fig. 10.—*Bacillus vascularum* from a culture on agar-agar, sweetened with about five per cent. of cane sugar, for comparison with figure 9. Cultures on agar-agar gave at first roundish colonies on the surface, having to the unassisted eye no structure either radiated or concentric. In the course of a few weeks the yellowish-white and somewhat opalescent growth had extended several inches along the edge of the tube on the surface of the agar-agar and *between* the tube and the agar-agar, without causing any liquefaction. On gelatine the growth was much slower, and remained circular and almost imperceptibly concentric. Its colour, &c., were as on agar-agar.

Fig. 11.—*Bacillus vascularum* from sugar-cane, stained with fuchein, and mounted in balsam. Compare Fig. 9.

strong evidence that the microbes are the cause of the disease, but it does not amount to proof. We may indeed say that if the injurious results of the disease follow solely from the plugging up of the sap-vessels, then the injury is due primarily to the *Bacillus vascularum*, but after all this is only a qualified statement.

Inoculations.

In order to show whether the disease is caused by the microbes, healthy plants were inoculated with gummy matter from diseased cane. I found it to be unnecessary to first make pure cultures in the way usually adopted, for the reason that a pure growth of microbes could be obtained without this precaution. Plenty of cane could be found containing no other organism in its interior tissues, and advantage was taken of this fact in making inoculations.

The method adopted will be of interest to students of plant diseases. The inoculations were performed with needles. These were prepared as follows:—A steel needle an inch long, mounted in a wooden penholder, was ground down on an oilstone until its diameter near the point measured one two-hundredth of an inch, and near the hilt one one-hundredth of an inch. The point was then converted, by grinding, into an exceedingly fine chisel or

wedge. The position of this wedge, which was of course invisible to the naked eye, was indicated by trimming the opposite end of the wooden pen-holder into a similar shape, and making its edge parallel to that of the invisible steel chisel. A second needle similarly mounted was ground down to about half the size of the first; its point was not in any way altered.

It was reasoned if the first needle was thrust into a stalk of healthy cane with its chisel-edge parallel to the fibres, that should it, as was very probable, strike a sap-vessel, the vessel would be split open with a minimum of injury, and if, when this needle was withdrawn, the second and smaller needle, bearing the virus, were thrust into the same hole that an inoculation would be accomplished. If this method were surrounded with the necessary precautions against foreign organisms it seemed as though it ought to answer.

The precautions alluded to were provided as follows:—The needles were mounted in test tubes as shown here (Fig. 12), and sterilised, tube and all, by heating in an oven for several hours at about 300° Fahr. A large glass-stoppered bottle was smeared inside with glycerine, and allowed to stand overnight. The rind was removed from a piece of selected gummed cane, and the end was trimmed well, and it was then placed in the glass-stoppered bottle. Just previously to being placed in the bottle its end was retrimmed with a sharp knife that had lain for several hours in an oven heated to about 300° Fahr. These operations were performed in a room as free from draught and floating dust as possible. It was argued that if the microbes were the only organisms in the selected piece of cane, then a needle could be prepared for inoculation purposes by simply dipping its point in the gum that oozed out while it stood in the bottle.

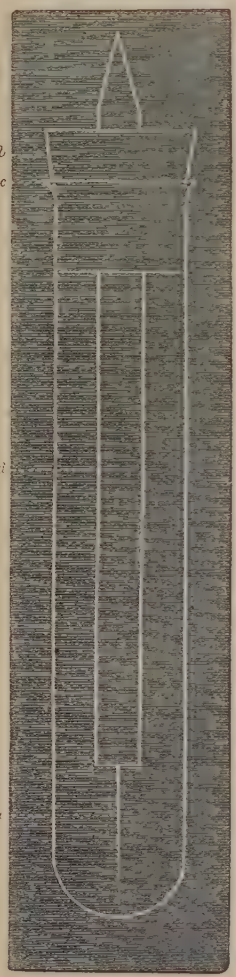


Fig. 12.—Diagram to show method of mounting and sterilizing inoculating-needle; *a*, wedge-shaped or chisel-shaped end of wooden pen-holder; *b*, cork; *c*, top of test-tube; *d*, wooden pen-holder; *e*, needle whose point is ground to correspond in shape and position with *a*, the top of the pen-holder.

Most careful observations were made both before the cane was selected and after the inoculations were over, to make sure that no other organisms were present.

When inoculating, the surface of the cane was first smeared with hot wax from a wick, the flame of which had been extinguished less than a second before. As chance would have it, the inoculations were made during weather when little or no dust was floating in the air, namely, after heavy rain. The inoculating needles were taken to the field in their tubes. The chisel-edged needle was inserted through the smear of wax into the cane for a distance of half an inch or more and withdrawn, to be immediately followed by the second finer needle bearing the microbes. The hole was then immediately covered with more hot wax, and the plants marked for further reference.

Origin, Distribution, and Prevalence of Gumming.

A farmer on the Lower Clarence told me that he saw gummed cane sixteen years ago on his farm; I have no doubt of it. The disease is probably nothing new, in fact, is very likely as old as the sugar-cane plant itself.

I think it very likely that the disease occurs wherever cane is grown. It is altogether improbable that it is confined to a small district in Australia. It occurs on the Richmond River as well as the Clarence. Cane-planters in Queensland have complained of a disease which is accompanied by the exudation of a yellow mossy substance. In describing the symptoms (page 783) such a phenomenon is noticed. It is extremely likely, therefore, that the Queensland disease is no other than gumming. Through the kindness of the Colonial Sugar-refining Company I have been able to examine a considerable number of specimens from the Tweed River and from Queensland. No gum was discovered in these specimens; this, however, does not show that gumming does not occur on the Tweed or in the district in Queensland from which these particular specimens were derived. I have seen gummed cane from one district in Queensland.

Where in the table on the opposite page the specimens examined are put down as healthy it is by no means to be inferred that the whole crop was free from gumming. The farms were visited with a small launch, and from three to six stalks were taken at random from as many different stools. The notes refer only to these few specimens. This table refers only to farms above Maclean or to the Upper Clarence. There is scarcely a farm on the Lower Clarence where gumming is not abundant, and on many of them its ravages are only too apparent.

These facts and observations show that gummed cane exists all through the Clarence River plantations, and I would warn the farmers above Maclean that, although up to the present they have escaped serious loss from this disease, they cannot in future count on doing so unless they take measures to guard against it. I have considered the matter very carefully, and can see no reason why, sooner or later, the up-river farms should not come to the same miserable pass as some of those down river if the same old procedure is to go on. Fortunately, the means of averting this calamity are at hand; a simple and inexpensive course of action, to be soon pointed out, will save much loss.

THE following is a table of notes made of the occurrence of Gumming on the Clarence River:—

Farmer.	Kind of Cane.	Stage of Growth.	Condition as regards Gumming.
Macintyre, South Arm	.....	.....	Thoroughly diseased.
Pateman, above South Arm	.....	One-year-old ratoon ...	Healthy.
Hadfield, Carl's Creek	.....	One-year-old ratoon ...	Traces of gumming.
Garvan, Jas., Palmer Island	Moore's purple	.....	One stalk out of three slightly gummed.
Millar, D., „	Daniel Dupont	One-year-old plant ...	Healthy.
Crispin, Geo., Grafton	Bamboo blanche	One-year-old plant ...	„
Macintyre, South Arm	Rapoe (supposed healthy sets from up river).	.....	Traces in every stalk. Examined six.
Girard	Rapoe	One-year-old ratoon ...	Three stalks out of five had traces of gum.
Johnson	.....	Two-year-old ratoon ...	One out of three had traces of gum.
Gullaford	Bourbon rosé	One-year-old plant ...	Healthy.
Robertson, Carl's Creek	Daniel Dupont	One-year-old plant ...	„
Gullaford, South Arm	Louizier	One-year-old plant ...	„
Garvan, Jas., Palmer Island	Old green ribbon	.....	Two or three stalks showed traces of gum.
Gullaford, South Arm	Bourbon blanche	.....	Healthy.
Robertson, Carl's Creek	Louizier	.....	„
Nunn, Arthur	Rapoe	Two-year-old ratoon ...	Four stalks, all gummed.
Millar, D., Palmer Island	China cane	.....	Two out of three healthy.
Yaeger, J. G., Woodford Island ...	Louizier, Daniel Dupont, Bamboo blanche, Bamboo rosé, Frost-proof.	.....	All healthy except Dupont.
Tarrant, below Grafton	Mauritius ribbon	One-year-old plant ...	Traces of gum in one out of five.
Yaeger, South Arm	Rapoe	One-year-old ratoon ...	Healthy.
McPhee, below Grafton	Mauritius ribbon	.....	One healthy, three suspicious.
Latimer, Southgate	.....	One-year-old ratoon ...	Healthy.

Prevalence.

Gumming at present prevails on the farms below Maclean, and is rare above Maclean. Why is this? It is not, so far as I could observe, because of any inferiority in the cultivation down river. I believe that our question is answered by the fact that the land in the lower part of the river contains more—that is, too much—moisture. Three things conduce to this—

1. The greater rainfall down river.
2. Clayey sub-soil within a few feet of the surface.
3. Lower river banks.

It need hardly be said that the greater the rainfall the moister the land will be; nor does it need to be pointed out that if there is within a few feet of the surface a sub-soil through which water passes only very slowly, what excess of moisture there may be in the soil will pass away slowly and imperfectly. Where the banks are low the slope or fall which causes the moisture to leave the land and enter the river is less, and for this reason the drainage is slower than it would otherwise be.

These reasons explain sufficiently the excess of gumming on the Lower Clarence, providing that it can be shown that the disease is assisted by wet land and imperfect drainage, and this is beyond question true, for in diseased fields it is apparent that the better-drained parts suffer less than the others, though all the conditions except this one of drainage are the same.

Spread of the Disease.

It seems evident that gumming is not a disease that is spread to any great extent through the air, as is so often the case with diseases of fungus and microbe origin. This is shown by an array of facts that cannot be for a moment overlooked. Some stalks in a stool may be badly gummed and others in the same stool fairly healthy; part of a crop may be gummed, and the rest remain in good condition; one field may be badly gummed, and an adjacent field perfectly healthy; the Upper Clarence is comparatively free from gumming, while the Lower Clarence has suffered severely for several seasons. All these facts are incompatible with the idea that the disease is very infectious. If healthy plants easily caught the disease by receiving the germs of it from elsewhere, borne on the wind, such a case as a healthy crop standing alongside a badly diseased one would be almost an impossibility.

On the other hand, the above facts are in harmony with the idea that the disease originates with the seed—the sets. When a disease is propagated in this manner, we expect that a crop from infected seed will be infected, or, if part of the seeds are bad and part good, some of the crop will likewise be good and the rest diseased. It is even the case that where a disease, as, for instance, smut in wheat, originates with the seed, that some stalks of a given plant may be much less diseased than others; thus, there may be ears bearing grain on the same wheat-plant with ears whose grain is completely destroyed by smut.

But there is no necessity to rely on these facts drawn from other crops. I was able to discover three cases on the Lower Clarence in which the crops were almost a total failure on account of gumming, where the planters, now that they know the nature and injuriousness of gumming, can recollect that the sets were badly gummed. They noticed the gum in the sets, which, when bad, is indeed very conspicuous, but not then knowing its nature, went ahead

and put in the sets notwithstanding. These three cases are those of very intelligent farmers, to converse with whom was to be convinced that they were quite right in their observations. In another case a farmer purposely took

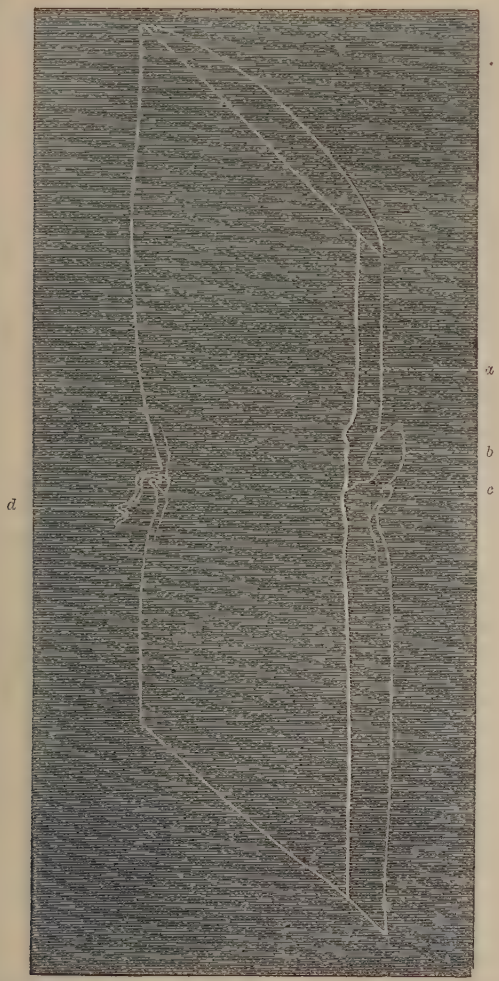


Fig. 13.—Diagram of a cutting of cane split in two to show the manner in which a diseased fibre of cane sends a diseased branch to the bud. *a*, the diseased fibre containing gum and the *Bacillus vasculorum*; *b*, the bud of the cane into which the diseased fibre, *a*, sends a diseased branch-fibre containing gum and the *Bacillus vasculorum*; *c*, base of the leaf which formerly covered the bud, and to which branch fibres are also seen to pass; *d*, a rootlet springing from the upper part of the node to which branch fibres also pass.

sets from diseased plants in order to see whether they would reproduce the disease. The disease was reproduced. I had an opportunity to examine the resulting plants, and can certify to the result.

On the other hand, on farms where the crops have been badly gummed, and in consequence almost a total failure, the introduction of sets from a district where the disease was not known to be prevalent has been followed by fairly healthy crops.

I am able to supplement these facts by others no less convincing. By carefully following up the branches of diseased sap-vessels at the joint of the cane-stalk I was able to trace them into the bud, and to show the presence in the bud of the gum and the *Bacillus vascularum*. From a number of examinations, I am convinced that this is generally the case in badly-gummed cane, so that in planting badly-gummed sets, *i.e*, sets out of which gum can be seen to be oozing, the farmer is actually setting out a diseased plant, the bud being of course actually the new cane-plant.

Remedies and Preventives.

1. *Sets.*—First in rank among the measures to be taken against gumming is care in the selection of sets. All other precautions will be in vain if gummed sets are planted. "Anything is good enough for seed"—that is one of the banes of potato-growing. I fear that it has not been without its pernicious effect on cane plantations. "No sugar-boiler will buy that piece there,—better cut it for plant-cane." Has the cane-farmer ever been guilty of this thought? Let him answer for himself. In some cases I fear his crops answer it but too plainly for him.

Sound sets are easily procured even without going off the Clarence, where gumming is most prevalent. Any cane-farmer can easily qualify himself to select them. Let him simply familiarize himself with the appearance of healthy cane, and then use no other for plant-cane. Of course selected sets will cost more labour or more money; but both will be wisely spent, and will be returned manifold at harvest time.

To select sets free from gumming proceed as follows:—Select a clean place and use a sharp knife (as sharp as a razor), and cut the cane into sets. Cut the stalks into sets from the top downward, and endeavour to cut nearer to the joint further away from the hand. I make this recommendation because the shock of cutting shatters the cane on the side away from the cutter, as can easily be seen on examining some cuttings. This shattering injures the resulting sets less if the cut is made as here directed. The inspection will be much easier and more thorough if the stalk is given a half turn with the left hand after each cut; both ends of a set can then be inspected easily as both will face up at the same time. As the sets are cut they should be stacked in long piles with the cut surfaces facing upwards. After half an hour or so, or more if in the shade, the sets may be inspected, and any gummed sets easily spotted and picked out. The inspection will be unsatisfactory unless the cuts are clean, and it will be found useless to attempt this operation with anything but a thin specially-sharpened knife. By following this method any farmer who has a fairly good crop may get sets fairly free from gum. I am inclined to think, however, that cane-farmers will find it more to their advantage to encourage a competent person to make a specialty of furnishing cane for plants. There are from 700 to 1,000 tons of seed-cane required annually on the Lower Clarence. If a plant-cane specialist had access to all the farms on the river, and had the privilege of buying at the market rate—that is, the sugar-mill rate—he could afford to put a good deal of time into selecting healthy cane for plants, and make a good living out of the business at from 25s. to 30s. per ton, providing, of course, he

received the patronage of the majority of the farmers. A man, to make a success of this business, would have to be a good judge of cane and its diseases, and possess the confidence of the farmers, and at the same time have business ability. He should have control of a launch and several punts, and a gang or two of cutters. At planting time his capacity would be taxed to its uttermost; at other seasons he should be on the look-out for fields from which to secure his plants for the coming season. Very likely this business could be combined with some other to advantage.

2. *Drainage.*—Good drainage decreases the loss due to gumming as well as those due to other diseases. The drainage on many of the farms on the Lower Clarence is not so good as it ought to be.

3. *Burning the Trash.*—When land is kept continuously under cane it is highly desirable to thoroughly burn the trash after each cutting. This destroys a vast number of germs—not only those of gumming, but of many other diseases, as well as the eggs and grubs of destructive insects. This is the common practice in the Australian cane districts, and to it no doubt they owe their comparative freedom from disease.

4. Land itself contains many of the germs of disease—that is to say, after the crop has stood on it for a length of time. Consequently, if one crop is followed by another of a different sort not subject to the same diseases, there will be less loss from disease than where land is left continually under the same crop. Whether this rotation of crops is advisable depends on the markets that are available. In the absence of rotation, a bare fallow once every few years does much good, both in renewing the strength of the soil and allowing diseases to run out.

5. *Seedlings.*—Where a crop is derived from cuttings from a previous crop, and not from seed, unless great care is used there is a gradual decadence in the quality of the crop; the variety runs out, as the saying is. This running out of varieties is much more noticeable in crops like cane and potatoes than in that of crops derived from seed.

Of late years considerable attention has been given to producing new varieties of cane by raising seedlings. Though the sugar-cane as it grows in New South Wales, produces, when allowed, a great quantity of seed-flowers, it produces very little fertile seed, so that considerable trouble has to be taken to produce a seedling. That it can be done, however, has been shown by Mr. M. H. Samson, of the Colonial Sugar Company, who has produced one such seedling. It is a thrifty-looking plant, which seems unusually robust, as is usual with seedling cane. It seems probable that varieties that have run out may be renewed or improved by raising seedlings from them. This is a line of experiment that is within the power of any cane-farmer, and one which is promising enough to be worthy of attention.

It is difficult to tell young seedling canes from grass-seedlings. On this account I would recommend that the seeds of cane be first sown in boxes of carefully baked soil. The baking will kill all grass-seed and other seed contained in the soil, so that whatever comes up after sowing cane-seed on such soil may be set down at once as cane. The seed should be sown on the surface, or be but slightly covered, and the soil should be kept moist and shady.

6. *Improving by Selection.*—While it is true that under ordinary care varieties of cane tend to run out, it is true that by extraordinary care the same varieties may not only be kept up to their standard, but improved upon. By systematically growing the same variety year after year, and carefully selecting only the very best for planting, a given variety may be

greatly improved, and so far as we know there is no limit to the amount of improvement. This should excite endeavour to use this simple method of making progress, and in fact does do so. The matter is mentioned here only because, in spite of the obviousness of the plan, it seems to be almost entirely overlooked by Australian cane-growers.

By selection cane can be improved in almost any direction we like—made to yield more to the acre, made richer in sugar, made hardier, made taller or shorter, softer or harder, in fact, as said, improved in any way we wish.

7. *New Sorts.*—There are plenty of sorts of cane grown in other countries that are unknown in Australia. The advisability of their introduction is beyond question, and the Government of New South Wales, through the Department of Agriculture, has done a good thing in importing many of these varieties. It is quite probable that the majority of the varieties introduced may prove inferior to those already grown here, but it is possible that some of them may prove superior, and this possibility should move every cane-grower, to be not only willing but anxious, to give them a trial on a small scale.

8. *Nurseries.*—A number of Australian cane-growers have established, near their houses, nurseries, in which they carry out our recommendations 5, 6, and 7. The plan is highly to be commended.

9. *Selection of Disease-resistant Sorts.*—This is a subject that needs an essay by itself. I am convinced that one of the greatest improvements destined to be made in agriculture is in the line of securing pest-resisting varieties. We stand as yet but on the threshold, yet we can clearly see the alluring prospect. What we now possess in a few cases, having obtained them almost by accident, shows how on the alert we should be to discover varieties as little subject to disease as possible.

Vasculin and its Properties (Chemical Tests.)

Vasculin, the substance formed by the growth of the *Bacillus vascularum* as it occurs in sugar-cane, is a yellowish, non-crystallisable, viscid substance, having an almost imperceptible acid reaction. The taste is that of a slightly soured solution of gum arabic. A short time after oozing out from the ends of cut cane by solution it converts ten times its weight of water into a fluid of the consistency of mucilage as used for adhesion purposes. Though soluble in water it is insoluble in alcohol. The addition of absolute alcohol to the raw substance converts it into a hard mass, but this is only owing to the abstraction of water; on placing the hardened mass in water it soon resumes its former consistency and appearance. Vasculin is not coagulated by alcohol.

Precipitation of the Watery Solution.

The following tests were made with watery solutions of the exudation from gummed cane. Great care was taken to procure only the growth due to the bacillus. Of course the solution tested contained an abundance of microbes, as it was found impossible with the means at hand to filter them out; but there is no evidence that this fact would interfere with the reaction.

The solution was precipitated by lime water; the precipitate re-dissolved on the addition of hydrochloric acid. The solution was similarly precipitated

Fig. 14.—Cane planted from sound and diseased cuttings. The plants in the foreground are from diseased sets, those in the background are from healthy sets.

by the hydrates of barium, strontium, potassium, and sodium, but was not precipitated by ammonium hydrate. In the case of barium, strontium, sodium, and potassium the precipitates were redissolved on the addition of hydrochloric acid.

Vasculin is therefore precipitated by the non-volatile alkalies but not by the volatile alkali.

Watery solution of vasculin was precipitated by lead acetate and ferric chloride, but was not precipitated by ferrous sulphate, barium chloride, or silver nitrate.

Action on Polarised Light.

The action of vasculin on polarised light was tested as follows:—628 milligrams of the air-dried gum were dissolved in ten cubic centimetres of water. It was necessary to make this quantity of solution up to 600 cubic centimetres before it became clear enough to test in the polariscope. This dilute solution was declared by Messrs. Moline and Samson to have no effect on polarised light. The same percentage by weight of cane-sugar in the solution would have given a reading of ·2. The half-length tube was used, so that this reduces to ·1, which was the lowest possible reading or limit of accuracy of the polariscope. It will thus be seen that the test was not satisfactory. The result, however, distinctly favoured the conclusion that the vasculin solution had little or no effect on polarised light.

Medicinal Properties of Vasculin.

Among the most important of all the properties of any substance are its effects on the human body. I took at one dose about 100 cubic centimetres of a thick solution of the crude gum, equivalent to about 10 grams of the air-dried gum. The taste was somewhat nauseating. There followed no change of temperature, disturbance of the pulse, or other effect on the system that I could observe. We may conclude from this that vasculin has no striking medicinal properties, and that the microbe of gumming is harmless to human beings, when taken internally.

Presence of Nitrogen.

Mr. Guthrie, chemist to this department, tested some of the raw gum qualitatively for nitrogen, with the result of showing that nitrogen was present. The amount was so slight, however, that it remains unsettled whether it was not derived from the microbes instead of the vasculin.

Action of Bacillus Vascularum on Solutions of Sugar.

The effect of the microbe of gumming on solutions of sugar was one that it was of prime importance to investigate. Any reduction in the amount of sugar caused by its growth would be of consequence not only to the sugar manufacturer, but to the brewer, and those who use sugar for other industrial purposes. The microbes occur in all the products of the sugar-mill, and even a slight fermentation due to its presence might be the cause of great

loss, and the same might be true in the brewery using sugar derived from a mill crushing gummed cane. I accordingly procured good samples of the gum, and having air dried it, placed weighed quantities of it in solution with weighed quantities of pure cane sugar as follows:—

On Saturday, 29th July, at 10 p.m., 457 milligrams of the air-dried gum were placed with 1 gramme of pure cane-sugar in 10 cubic centimetres of water, this quantity being used as approaching the constitution of cane juice. Precautions were taken against dust and accidental contaminations. On Tuesday, 1st August, at 11 a.m., the whole was tested for sugar. There was no reduction in the amount of cane-sugar. A check was kept in the shape of 1 gramme of sugar dissolved in 10 cubic centimetres of water. This also remained unchanged.

This experiment was repeated with even greater precautions, but with the same result. There was no reduction of the amount of cane-sugar due to the presence of the microbe.

The amount of sugar in Gummed Cane.

In selecting the specimens for the following comparative analyses I took great pains. I secured seven badly-gummed canes and seven canes nearly, but not entirely, free from gum, both lots from the same crop. Every precaution was taken to have the two lots as near alike as possible, except in the matter of gum. In this latter respect the one lot contained much gum, and the other only traces. It was found necessary, in order to match the gummed specimens in ripeness and colour, to use for the second lot cane that appeared over-ripe. There were no canes in the crop that were entirely free from gum. The canes of the two lots were matched in pairs, one of each pair being gummed and the other not, or practically speaking, not. Of a pair, each specimen had the same length and number of joints, and they were of the same diameter, and were taken from the same part of the cane, and neither was allowed to show traces of any other disease than gumming. In a word, every precaution that could be thought of was taken to have the samples vary in but one respect, namely, the presence of gum. The results were obtained by digesting the chopped up cane in the usual manner, and were as follows:—

Analyses of very slightly and badly gummed cane for comparison:—

	Very slightly gummed.	Badly gummed.
Per cent. of cane sugar	12·50	10·50
Per cent. of fruit sugar	·82	·88
Per cent. of other organic matter and soluble ash ...	1·91	2·36
Per cent. of total solids	15·23	13·74
Quotient of purity	82·1	76·4

Some of the same chips were pressed by hand, and the juice thus expressed was tested for sugar, with the following results:—

	Very slightly gummed.	Badly gummed.
Percentage of cane sugar	14·90	11·50

The raw juice squeezed out by hand having stood 48 hours was tested with decinormal solution of sodium hydrate.

	Very badly gummed.	Slightly gummed.
100 cubic centimetre required of $\frac{N}{10}$ Na OH	3·8 cubic centimetres.	3·2 cubic centimetres

Conclusions drawn from the results of the Chemical tests.

These various tests to which the gum was submitted lead to several important conclusions.

First, the fact that hydrate of lime precipitates the gum from watery solution and from cane juice, shows that the present practice of precipitating the organic matters in the juice as it comes from the rollers, has the effect of getting rid of any gum that may be present in the juice from gummed cane in the feed. This is an important fact inasmuch as if this were not the case and the lime failed to precipitate the gum, the presence of so much organic matter in the juice would interfere seriously with the boiling and crystallisation. Where cane is being used part of which is gummed, the amount of organic matter in the juice will certainly vary much from hour to hour and even from minute to minute, and consequently the regulation of the supply of lime to such juice needs special attention to secure the best clarification. It seems quite likely that it is a failure to give this special attention to the clarification that has given rise in some sugar mills to a most serious loss of sugar owing to lack of crystallisation in the jellies. Beyond doubt juice containing much gum is more difficult to clarify. In some cases the most careful addition of lead acitate fails to completely clarify such juice. Lime has a similar limit in its clarifying action. There is good reason to believe that this lack of clarification is not due to a failure to precipitate all the vasculin, but a failure to precipitate the microbes. In the mill these certainly go on. I have seen the *bacillus vascularum* in every product of the mill while it was handling gummed cane. The presence of these microbes in the jellies may mechanically prevent crystallisation or even by their growth cause other deleterious disturbances. The only present remedy for such a state of things is great care in the clarification. The sharper and more complete the precipitation of the organic matter is, the more microbes it will remove mechanically included in the precipitate. If the subsequent growth of the microbes is possible, which seems not to be the case judging by their action on sugar solutions, it may be that superheating the juice would sterilise it and so get round the difficulty. This would be a problem for the engineer, but it is one that in the present state of our knowledge of the question it would be unwise to take up. It might be worth trial to handle gummed cane by itself, giving special attention to the clarification, or at least where there are two crushers, to feed the gummed cane to only one, and regulate a separate supply of lime to the gummy juice.

I observed that the sooner gummy juice was clarified the more perfect was the result, and I believe that if the lime could be added immediately after the cane has passed the first rollers, it would be a distinct gain, apart from preventing inversion by the gain in time.

The second fact of importance brought out by these tests is the low percentage of sugar in gummed cane. Even where the crop grows sufficiently well to be marketable, the percentage of sugar is much less than it otherwise would be. Its market value is therefore so much the less ; and this loss must be *subtracted from the margin of profit*, for it costs just as much in every way to raise a crop of gummed cane or to convert it into sugar afterwards, as to do the same for a sound crop.

The third fact of importance is that the raw sugars from mills using gummed cane may be used with impunity by brewers. They need not fear that by using it they will introduce into their vats an organism that will interfere with the fermentations, for I have shown that the *bacillus vascularum* is not one that acts, to any appreciable extent, on sugary solutions, even where they contain starchy matter.

II. Fungus Diseases of the Sugar-cane.

Of course the various parasitic fungi found attacking the sugar-cane demanded and received a good amount of attention. In all, seven sorts were examined. The damage done by some of these is considerable, but is small in comparison with that done by the disease described under the heading of "Microbes."

1. Cane Rust.

Uromyces Kühnii, Krüger.

This fungus is common throughout the Clarence district wherever cane is grown. It is not, however, the fungus commonly referred to by the farmers as rust. The fungus to which the farmers give the name rust will be described later on; it is not only not a rust,—it even belongs to a very different class of fungi. The present fungus, the true cane-rust, presents itself in the form of elongated brownish or blackish narrow streaks on the leaves of the cane, more particularly on the under side.

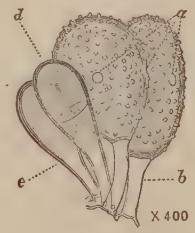


Fig. 15.—Two spores and two smaller paraphyses of the cane-rust; *a*, germ-pores of the rust-spores (uredo-spores); *d* and *e*, paraphyses with brownish walls; *d*, two-celled; *e*, one-celled; *b*, pedicil of one of the uredo-spores. The brown or orange, obovate to ellipsoidal, rather thin-walled, echinulate uredo-spores, measuring 47 — 53 μ × 28 — 35 μ, possess four equatorial germ-pores, and are borne on pedicils, somewhat shorter than their own length in elongated or linear, brown, purple, or black sori, one-fourth of an inch to one inch long, occurring either singly or confluent, more particularly on the under side of the leaves. Teleutospores not seen.

The best specimens of the fungus show a light-brown powder, the spores, issuing from a crack in the dark streak; but more often the growth of spores is meagre, and they can be secured only by inserting the point of a needle into the rupture that almost invariably occurs in the epidermis of the leaf, and passing it lengthwise through the pustule. The discolouration of the cane-leaf that occurs in consequence of the attack of its rust fungus is similar to that observed in wheat and maize. It is needless to say, however, that the rust of the sugar-cane is totally distinct from that of wheat or maize, and that there is never any transfer of the disease from wheat to sugar-cane, or *vice versa*. The first indication that the cane-leaf is attacked by rust is a loss, in spots, of the green colour. At the point of attack, which is always small at first, the natural bright green of the cane-leaf gives place first to a light green, then to yellow, and later still to

an orange colour. Finally, as the spores mature, the pustule grows elongated as indicated by the discolouration becoming a narrow streak. At last the fungus breaks through the epidermis of the leaf, and the spores escape. At this time the pustules, or diseased spots, are brown or purple or purplish black, but always much elongated and narrow. They are often an inch in length, but seldom more than a sixteenth of an inch wide. Often several pustules run together, and thus produce irregular streaky patches. When the spores escape they germinate during dewy nights or moist weather, and if lying on a cane-leaf the germinal thread enters through one of the breathing pores, and by its growth produces a fresh discolouration and ultimately a new pustule.

The size of the cane-rust spores is such that it would require eight hundred laid side by side to reach an inch. They are, therefore, quite microscopic, and being very light they are blown hither and thither by the wind, and in this way the disease is spread from field to field.

Fig. 16.—Unripe and colourless uredo-spore of cane-rust germinating in a peculiar manner—not from one of the germ-pores, but from the broken base of the spore; *a*, the spore; *b*, base of the sprout or promycelial thread; *c*, *c*, septa; *d*, end of the mycelial thread.

The form of the spores is well shown in the adjacent wood-cuts.

The amount of damage done by the cane rust, as seen by me on the Clarence River, is very small, and does not call for any remedial measures beyond the general one of burning the trash, and even this measure would not be advisable as a measure against rust alone, as the gain would not be worth the cost. When, however, other things are taken into consideration, as will be shown later on, this precaution is an advisable one.

2. Cane Spume.

Strumella sacchari.

The name Spume I originate and apply to the disease of sugar-cane caused by the fungus *Strumella sacchari*. This fungus is well known to all cane-growers, being one of the most prominent and striking fungi that attack their crop. It occurs in the stalk and leaf after they are dead, or nearly so, in the form of conspicuous black eruptions which in damp weather, especially if it succeeds a period of dryness, exude a black kinky thread. When the eruptions are numerous these threads give the cane the appearance of having made a growth of kinky, coarse, jet black hair. If one of these threads is placed in water and examined under the microscope it is found to be composed almost entirely of spores of the form shown in figure 19. These are held together by a glutinous substance, and this is why they come out in such a peculiar excrescence. Under the influence of spume the internal tissue of the cane becomes dry, light, and nearly white.

The common opinion among cane-growers is that spume appears only on dead cane or cane already injured through borers, frost, or some other cause,

and that, therefore, it is not to be regarded as the cause of much damage. Some even assert that it attacks only dead cane. This latter assertion is a mistake, as anyone can easily see who visits a cane-field, for he will find plenty of the fungus, both on the leaves and stalks of living cane. I believe it is true that in most cases, if not all, this fungus requires the cane to be first in some way injured. Perhaps the frost so injures the arrow of the cane as to cause it to decay and die; perhaps a borer makes its way into the cane, and thus breaks the rind; or, again, perhaps the wind twists the stalk and cracks it, or the cane gets the rind injured in any of the numerous possible ways; then this fungus stands ever ready to take advantage of the accident, and in a few weeks' time makes such an inroad as to send the whole cane well on its way to decay. The spores of the *strumella* exist in countless millions over the whole Clarence River district, and the chance of an injured cane escaping from them is very small indeed. As soon as one of the spume spores alights on an injury, it sprouts and enters the tissue of the cane, and by its growth inside the cane causes the adjacent rind to lose its natural colour, become brown and shrivelled. At last the diseased area becomes very light brown, or even almost white, and then there appear on its surface numerous pimples, which, when they break, emit the kinky black threads already described. The spores composing these threads are so small that one of the threads half an inch long would contain a million and a quarter of spores. Sometimes only a limited portion of the cane shows those appearances, and this is usually the case when the fungus enters through some very small injury to the rind; quite as often, however, the whole cane is attacked, and dies down to the ground. In many fields on the Lower Clarence stalks dead and covered with spume may be counted by thousands, and there are no fields altogether free from the disease.

Fig. 17.—Cutting from a cane that has been killed by the attack of the fungus *Strumella sacchari*. The fructification of the fungus is shown as numerous black spots *a*, *a*, *a*, &c. The spores of which these black patches are composed are shown in Fig. 19.

The amount of damage done by spume is difficult to estimate. There is no doubt that, through its agency, much cane, which, though injured, would

be saleable, is soon rendered worthless. Let the cane farmer go into his field, and count in one row the dead stalks showing the black pustules of

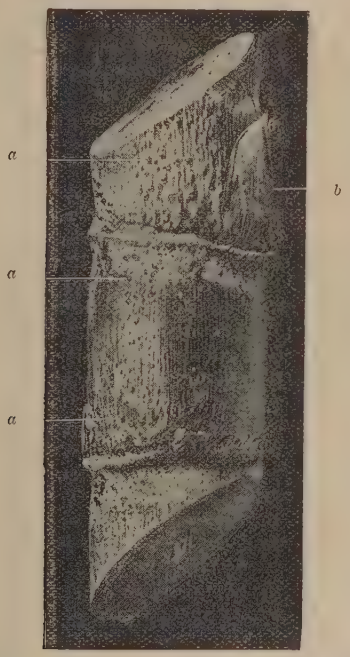


Fig. 18.—Cutting from cane attacked by spume. The fungus has fruited in the black spots of which *a a a* are examples. A bud is shown at *b*.

spume, and multiply this by the number of rows in his field, and he will soon know the amount of his loss in this direction, and he can then tell how much he can afford to spend in combating it.

It must always be remembered, however, that spume is probably only a secondary disease—one that comes after other causes have made an opening for it.

The practice of burning the trash after harvest is one that very much reduces the number of spume spores, and is on that account highly to be commended. Thoroughly burning the trash destroys countless millions of the spores, many of which might otherwise live to propagate the disease.

Fig. 19. -Spores of *Strumella sacchari*. With them are shown two crystals of oxalate of lime; these crystals occur among the spores.

3. Cane Soot.

Macrosporium graminum.

Soot is a term I apply to those diseases accompanied by the appearance on the leaves or other parts of plants of the minute, sooty-black, rather loose growths of one of the spore-forms of species of *Macrosporium*. These growths are smaller than a pin's head, and, when numerous, give the plant

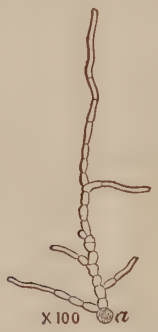


Fig. 20.—Spore of the cane-soot germinating in water; *a*, the spore. The nearly-colourless mycelium is many-septate and much-branched.

much the appearance it would have after a light shower of fine soot. Like soot, these black outgrowths are easily brushed away, their attachment to the plant being very slight indeed. In some cases these fungi do considerable harm, as, for instance, in the case of wheat, but I have seen no evidence that the soot of cane injures the crop in a manner worthy of special attention. In the crease on the side of the cane above the "eye" there often occurs a black or dark-brown substance. This must not be confounded with soot, to which it bears only a slight outward resemblance. When the cane soot is examined with a microscope, it is found to be composed almost entirely of dark olive-coloured spores, round, like a ball. These spores, though small, are much larger than the generality of fungus-spores, being about the hundredth of an inch in diameter. The explanations of the accompanying figures furnish further information concerning this fungus.

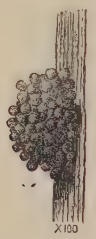


Fig. 21.—Spores of a soot-fungus to give an idea of the appearance of the cane-soot fungus as it occurs on the leaves. The nearly-black spherical spores are borne in black clumps less than one-hundredth of an inch in diameter, and these are scattered over both surfaces of the cane-leaf.

Fig. 22.—Spore of the fungus shown in Fig. 21 more highly magnified.

4. Cane Freckle (erroneously called Rust).

This is a disease confined more particularly to the leaves, and is that which Australian cane-growers often call rust. As stated on p. 799, the term rust should be applied only to the disease caused by the rust-fungus of the cane. It is misleading to apply the term to the present disease. As there has, however, been no suitable common name attached to the disease now under consideration, I suggest that the name *freckle* is very suitable, it being plain, short, descriptive, and convenient.

Cane freckle, then, is a disease of the sugar-cane, accompanied by a freckled appearance of the leaves, and is caused by a fungus, or it may be by more than one fungus. The freckles are sometimes round, but more often are elongated

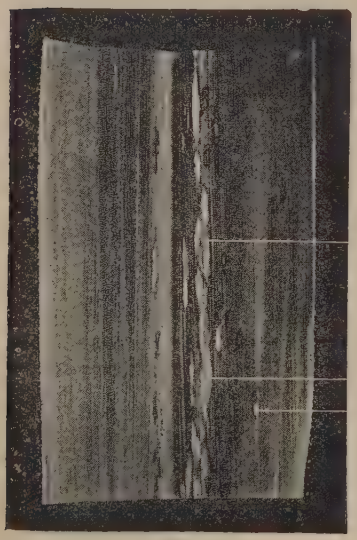


Fig. 23.—Portion of a cane-leaf, showing the yellow, brown, and purple freckles (*a*, *b*, and *c*), due to the attacks of the fungus.

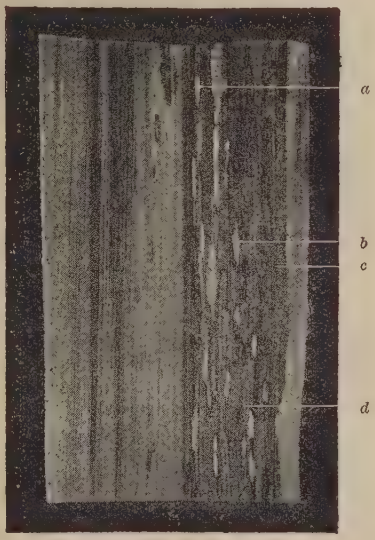


Fig. 24.—Another sample of the freckle. The spots *a*, *b*, *c*, *d*, &c., are those referred to in the adjacent text.

or irregular, their diameter varying from a small fraction of an inch to several inches; their colour is various, and depends on the stage of the disease. At first there are merely slight alterations in the natural green colour of the leaf; later they take on various shades of yellow, red, purple, and brown. In general the centre of the freckle is lighter in colour than the margin, and it is here that the tissue first becomes dead and assumes the characteristic colour of dead cane-leaves. It is here, too, that the fungus that causes the freckle first produces fruit, as is indicated by the appearance of minute black spots, which, when torn open with fine needle-point and examined under the microscope, are found to contain mycelium and spores. The mycelium of the fungus extends throughout the area of the freckle, and it is owing to the growth of the mycelium that the freckle increases in size. The margin

of the freckle always shows all the stages of the decay of cane-tissue, as is indicated by the various coloured bands of which it is composed, these bands varying from yellow, through red and purple, to black. A cane leaf may bear only a few freckles, scattered here and there on its surface, or it may have them located in patches. As the freckles increase in size they often run together and form large diseased patches. That portion of the cane-leaf not freckled retains its green colour for some time if the freckles are few and scattered; if, however, the freckles are confluent, the leaf is killed in the course of time.

Freckle does more harm to the leaves of cane than any other fungus disease I have seen on the Clarence River. The total damage done by it is,

Fig. 25.—*a*, one of the four-celled spores of the sphæriaceous fungus causing freckle; this spore is germinating and sending out a septate mycilliæ thread from each end; *b*, microbes found in the same preparation; *c c*, yeast-cells found in the same preparation.

however, rather insignificant, and calls for no special remedy. The practice of burning the trash after harvest is beneficial in destroying the spores of the freckle-fungus, and on that account is to be recommended.

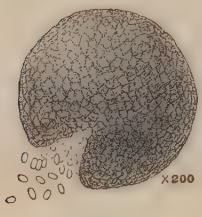


Fig. 26.—Perithecium, of a species of Phoma (*Phoma sacchari*, Sacc ?), found on the leaves of freckled cane. The spherical, black, erumpent perithecia measured one two-hundredth of an inch in diameter, and contained a multitude of colourless spores, measuring 8 μ × 4 μ. The perithecium here represented was broken open artificially.

Fig. 27.—*Botrytis*, found on leaves of freckled cane. The dark olive-coloured or almost black septate hyphæ were half a millimetre or more high, and bore on a few short branches at the summit, a closely-packed cluster of from 50 to 100 unicellular, elongated, olive-coloured, ellipsoidal, thin-walled, finely verucose spores, measuring 18 μ × 8 μ.

While it is certain that freckle is caused by fungi, I am by no means certain that my investigations answer satisfactorily the question "What fungus?" A species of *Sphaeria* is common at the centre of the freckles, and I observed also on badly freckled leaves sporangia of the form shown in the adjacent wood cut. It may be that these are another spore-form of the *Sphæria*. One of the spores of the *Sphæria* in process of germinating is shown in Fig. 25; with it are shown forms of yeast and bacteria, common on injured cane everywhere.

Another fungus may be mentioned in this connection as it was found on freckled leaves, though after they were dead; I cannot, therefore, be certain that it is a true parasite as is the case with all the fungi previously mentioned. The dead leaves often exhibit an outgrowth of excessively short and scattered short black hairs, or rather what appear to the unaided eye as such. When these objects are examined microscopically, however, they are seen to have the form shown in Fig. 27. This fungus was not very common, and is perhaps of no economic importance.

5. Red Rot of the Cane.

The disease which I term red rot is of fungus origin, and is one which occurs more particularly in the stalk of ripe cane, where it does a considerable amount of damage. The fungus causing the disease is a true parasite, and seems to have the power to enter healthy cane without any such aid as that required by spume. The appearances produced by the disease are very characteristic and striking. The internal tissue of the cane becomes first pink, then red, and finally brown. The tissue does not dry up as in the case of spume, on the contrary for a considerable time at least it remains juicy, though the juice contains less sugar than that of equally ripe healthy cane. The fibres of cane affected with red-rot becomes even more strikingly coloured than the remaining tissue, as will be seen by splitting the cane open; the fibres will stand out prominently as red, brown, or black streaks according to the stage reached by the disease. If a thin slice be taken across the cane

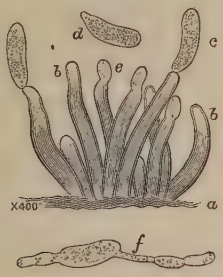


Fig. 28.—Section through one of the minute black pustules of the fungus causing the red-rot of the sugar-cane—*a*, the surface of the cane-stalk; *b*, aerial hyphæ from which the spores have already fallen; *c*, a spore still on its hypha or stalk; *d*, a spore ripe and fallen off; *e*, a spore in process of formation; *f*, a spore that has begun to germinate. The elongated and slightly arcuate unicellular, almost colourless, thin-walled spores measure 6 μ × 25 μ, and were borne singly on olive-green unbranched hyphæ, clustered together in pustules, only about a quarter of a millimetre long, which occurred in multitudes on dryish-looking finely striated areas on the surface of the stalks of sugar-cane.

and examined under the microscope it will be seen that the mycelium of the fungus is more abundant in the neighbourhood of the fibres, and this doubtless explains why they are the first to exhibit the reddish colours so characteristic of the disease.

It is some time after the above internal symptoms appear before the fungus causing the disease makes its appearance at the surface of the cane. The surface of the cane loses its glaucous colour, owing to the disappearance

of its natural white waxy covering, and assumes a ripe or over-ripe look. That part of the surface where the fruit of the fungus is to appear turns brownish, and often has a very distinct contour. On this area the skin becomes finely striated in a longitudinal direction, and among the striations are to be seen a multitude of minute dark points; these points are the fruiting points of the fungus, and if they are examined under a lens of high power they appear as shown on the preceding page. The spores are very minute and numerous, and through their agency the disease spreads from cane to cane and from field to field. The reader will easily judge of their minuteness when he learns that it would take more than a million of them to cover one side of a silver three-pence.

The damage done by red-rot is considerable, and consists largely in a reduction of the amount of available sugar in the cane. As seen by me on the Clarence River, this disease seldom killed the cane outright, but seemed to bring on a premature ripeness, so that the crops worst attacked contained much of what was pointed out to me by experts as *over-ripe* cane. Not invariably, but very often, over-ripe-looking cane showed an abundance of red-rot. The disease is more prevalent in otherwise unhealthy crops than in otherwise sound crops.

No remedy has suggested itself for this disease beyond the general one of burning off the trash after harvest.

Destroying Trash.

Taken altogether, the foregoing diseases of fungus origin more or less prevalent on the Clarence River sugar farms do an amount of damage which may possibly equal two per cent. of the value of the crop; it is not likely that the loss much exceeds one per cent. Considering the variety of the diseases and the different parts they affect, it is plain that no remedial measures will pay except such as are applicable at the same time to all. One such measure is worthy of strong commendation, namely, burning off the trash after harvest. This measure is one already well understood and generally practised. The only argument ever brought against it is that the burning destroys a lot of material which if ploughed in would be valuable as manure. This argument might have some force where a rotation of crops is in vogue, and where the land lacks vegetable matter from which to form humus; but where, as is the case in most, if not all, Australian cane-growing districts, no rotation of crops is practised, and cane is made to follow cane year after year, the argument loses all its force because of the following fact:—Unless the non-marketable and otherwise useless material left over after the crop is removed, is destroyed, the spores of various diseases will remain over to infect the next crop, and that crop will in consequence suffer more than the previous one, and so on. In this manner, where land is kept year after year under the same crop, the diseases of that crop are bound to accumulate and cause more and more loss as time goes on. So long, therefore, as cane-farmers continue to keep their land continuously under cane, the burning off of trash is highly to be commended, and the more thoroughly it is done the better. Any cane-grower can easily familiarize himself with most of the diseases of his crop, and when he comes to burn off his trash let him bear in mind that the greatest good he does by burning it is the destruction of the germs of disease. With this thought in mind he will be more likely to be thorough than if he regarded the burning merely as a means of getting rid of a lot of stuff that is lying around in the way.

III. Nematode Worms found attacking Sugar-cane.

A good deal has been said and written about the possibility or probability of nematodes being the cause of certain diseases occurring in the sugar-cane of Java. The *Tylenchus sacchari* of Soltwedel has been pointed out by one writer as a probable cause of the cane disease known as Sereh. The measurements of this worm, as given by Dr. Krüger, are $\frac{2{\cdot}6 \quad ? \quad ? \quad M \quad 92{\cdot}}{1{\cdot}9 \quad ? \quad ? \quad 2{\cdot}9 \quad 2{\cdot}4}$ ·98 mm. and $\frac{2{\cdot}1 \quad ? \quad ? \quad -86{\cdot}60 \quad 95{\cdot}}{2{\cdot} \quad ? \quad ? \quad 2{\cdot}4 \quad 1{\cdot}9}$ 1·04 mm. The worm has distinct lips and a well-developed spear. The tail of the female is conoid to the blunt terminus; that of the male is more pointed, and is supplied with a bursa which extends a short

Fig. 29.—Diagram in explanation of the descriptive formula used for Nematode worms; 6, 7, 8, 10, 6 are the transverse measurements, while 7, 14, 28, 50, 88 are the corresponding longitudinal measurements. The formula in this case is:—

$$\frac{7{\cdot} \quad 14{\cdot} \quad 28{\cdot} \quad 50{\cdot} \quad 88{\cdot}}{6{\cdot} \quad 7{\cdot} \quad 8{\cdot} \quad 10{\cdot} \quad 6{\cdot}}$$

The unit of measurement is the hundredth part of the length of the worm, whatever that may be. The measurements become, therefore, percentages of the length. The measurements are taken with the animal viewed in profile; the first is taken at the base of the pharanx, the second at the nerve-ring, the third at the cardiac constriction, the fourth at the vulva in females and at the middle (M) in males, the fifth at the anus.

distance in front of and behind the anus, and when the worm is viewed in profile extends beyond the ventral contour. The spicula, as figured by Dr. Krüger, are acute and cuneiform, and do not exceed the anal body-diameter in length.

In view of the above facts, it was thought best to inquire what nematode worms are to be found in cane-fields on the Clarence River, more especially about the roots of the sugar-cane. Inasmuch as the mere presence of a given species among the roots of cane, would be no proof that it was injurious to, or in any way specially connected with, the cane, specimens of soil from about healthy cane were examined, as well as from about diseased cane. Specimens of soil from cultivated fields under other crops than cane and specimens of virgin soil were also examined. In this way it was possible to come to definite conclusions. The result showed conclusively that most of the species of nematode worms found about the roots of diseased cane-plants occur also equally abundantly about those of healthy cane. Most of the species found in cane-fields occurred in other fields not under cane, and many were found about the roots of native plants in virgin soil.

The following are the descriptions of these worms, arranged under the genera to which they belong. There are in all thirty species, belonging to fourteen genera, of which three are new. Nearly all the species are sorts never hitherto described, only four of them being already known.

1. Dorylaimus.

The genus *Dorylaimus* comprises many worms found in the soil and on the surface of land plants. They derive their food from rootlets and other parts of plants. Their method of feeding is similar to that of the worms composing the genera *Tylenchus* and *Aphelenchus*. They first pierce the tissue of the plant with a spear or sting contained in the pharynx or throat, and which they have the power to thrust forth at will. From the wound thus made they suck up the juices of the plant. These worms differ materially from *Tylenchus*, however, not only in habit but in structure. Many species of *Tylenchus* are parasitic. But thus far no *Dorylaimus* has been shown to be a parasite. They appear always to inhabit the soil and to attack the roots from the outside. In harmony with this mode of life they

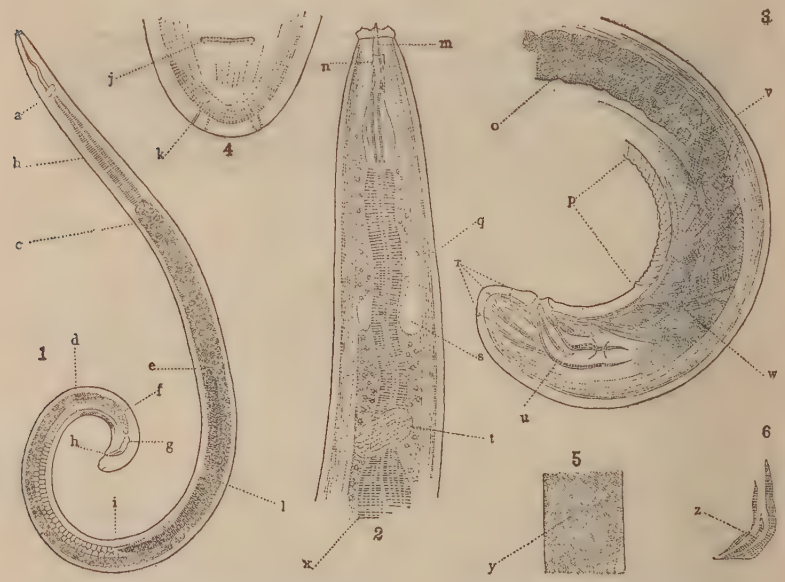


Fig. 30.—Anatomical details of *Dorylaimus perfectus*; 1, male worm magnified; 2, head and anterior part of the neck of the same worm more highly magnified; 3, tail end of same worm more highly magnified; 4, posterior end, ventral view; 5, a portion of the intestine; 6, spiculum.

a, nerve-ring.
b, œsophagus.
c, intestine.
d, intestine.
e, blind end of anterior testicle.
f, pre-rectum.
g, spiculum.
h, anus.
i, blind end posterior testicle.
j, anus.
k, papillæ.
l, junction of testicles.
m, spear.
n, spear-guide.
o, intestine.
p, papillæ.
q, outlet of gland.
r, papillæ.
s, gland.
t, nerve-ring.
u, left spiculum.
v, oblique copulatory muscle.
w, oblique copulatory muscle.
x, œsophagus.
y, tersellation of intestine.
z, spiculum.

are, as a rule, much larger than *Tylenchi* or *Aphlenchi*, some of the larger species being above half an inch long. They are never gregarious. The reader will easily familiarise himself with the form and structure of these worms by consulting the accompanying illustrations. The points that serve to distinguish this genus from other similar ones are, the form of the spear

or sting, the form of the œsophagus, and the presence in front of the rectum of a modification of the intestine, to which I have given the name of pre-rectum. The base of the spear has no bulbous swellings. The œsophagus is narrow in its anterior part, but near the middle it expands and becomes henceforth large and muscular. There are no sucking bulbs.

1. *Dorylaimus minutus*, n. sp. $\frac{\cdot5 \quad 14\cdot \quad 28\cdot \quad {}^{35}\text{`}68\text{''} \quad 98\cdot7}{1\cdot5 \quad 3\cdot8 \quad 4\cdot1 \quad 4\cdot \quad 2\cdot3}$ ·64 mm. Cuticle devoid of hairs, likewise of striæ. The conoid neck ends in a rather rounded head, destitute of setæ, but bearing six lips, each with two papillæ. The lip-region it set off from the head by a constriction. Neither eyes nor lateral organs were seen. The spear is rather weak, and its guiding ring but faintly to be seen. In its anterior part the œsophagus is one third as wide as the corresponding part of the neck; a little behind the middle, however, it rather suddenly becomes two-thirds as wide as the neck. The lining of the œsophagus is thick, and in optical section is plainly to be seen. The beginning of the intestine is obvious, rather on account of the change of structure and colour than because the cardiac constriction is distinct. The cardia is flat and inconspicuous. The intestine is thick-walled and two-thirds as wide as the body; its component cells are large, and the lumen consequently narrow and somewhat zigzag. The rectum is equal in length to the anal body-diameter. No pre-rectum was discernible. The lateral fields were one fourth as wide as the body. The nerve-ring encircles the œsophagus somewhat obliquely. The bluntly conoid tail is only twenty micromillimetres long, and contains no caudal glands. The anus is inconspicuous. The vagina is half as long as the body is wide. The size and shape of the eggs remain unknown. The posterior ovary is smaller than the anterior; the reflexed part of each extends two thirds the distance back to the vulva.

Habitat: About the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

2. *Dorylaimus subsimilis*, n. sp. $\frac{\cdot6 \quad 6\cdot \quad 24\cdot \quad {}^{30}\text{`}54\text{''} \quad 98\cdot7}{1\cdot1 \quad 3\cdot \quad 3\cdot3 \quad 3\cdot5 \quad 2\cdot1}$ 2· mm Neck conoid, especially anteriorly, where it is also somewhat convex. The lip region is set off by a distinct constriction, and is one fourth as wide as the base of the neck. Lips six, low, confluent, each with two papillæ as usual; here, however, rather inconspicuous. No eyes. Spear well developed; its guiding ring distinctly to be seen. Posterior part of the œsophagus two-thirds as wide as the corresponding part of the neck, the expansion taking place gradually near the end of the anterior third; the lining distinctly to be seen. Cardiac collum shallow, though distinct. Intestine three fourths as wide as the body, dark. Rectum equal in length to the anal body diameter. Pre-rectum over twice as long as the rectum. Longitudinal fields one fifth as wide as the body. Nerve-ring encircling the œsophagus at a slight angle. Tail hemispherical-conoid; anus distinct; caudal glands absent; terminus blunt or rounded. Vagina conspicuous, and the position of the vulva therefore easily made out. Reflexed ovaries reaching back to the vulva.

Habitat: About the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

3. *Dorylaimus pusillus*, n.sp. $\frac{\cdot8 \quad 12\cdot \quad 25\cdot \quad {}^{25}\text{`}48\text{''} \quad 82\cdot}{1\cdot3 \quad 3\cdot \quad 3\cdot4 \quad 3\cdot \quad 2\cdot1}$ ·9 mm. No markings were seen on the cuticle of this species, and the skin was, as usual in this genus, destitute of hair. The conoid neck was surmounted by a truncate head, bearing six small lips, each with the usual two papillæ. No

lateral organs were seen, and there were no eyes. The spear was well developed, being one third as wide as the lip region. The anterior three fifths of the œsophagus was only one third as wide as the corresponding part of the neck, but the remainder was twice as wide, the change in width taking place rather abruptly. The lining of the œsophagus appeared as a distinct double line. Though the cardiac collum was shallow it was distinctly to be seen. The olive-coloured intestine was two thirds as wide as the body, being granular and rather thin-walled. A large and conoid cardia projected into the cardiac cavity. The rectum was twice as long as the anal body-diameter, being of the same length as the pre-rectum. The tail tapered rapidly in the anterior third, thence onward it was narrow and ended in a fine point. There were no caudal glands. The vulva was always easily found on account of the prominence of the transparent chitinous vagina, two-thirds as wide as the body. The reflexed ovaries reached one-half to two thirds the way back to the vulva.

Habitat: Roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia; also among roots of moss, Maclean, on the same river.

2. Brachynema, new genus.

All that is at present known concerning this genus is comprised in the following description of the first discovered and only known species.

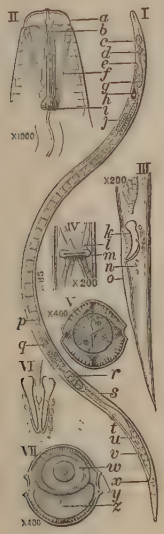
1. *Brachynema obtusa*, n.sp. $\frac{3{\cdot}3 \quad 10{\cdot} \quad 25{\cdot} \quad \text{Y} \quad 98{\cdot}}{3{\cdot}8 \quad 7{\cdot}3 \quad 7{\cdot}8 \quad 8{\cdot}7 \quad 4{\cdot}3}$ ·6 mm. The foregoing formula is only approximate and represents the measurements taken from two young worms of this new and interesting genus. The cuticle seemed destitute of striæ. The conoid neck, which seemed endowed with a considerable power to expand and contract in length, terminated in a rounded head containing a spear 24 μ long and resembling that found in the pharynx of *Tylenchus*. Six stump-like setæ occurred on the margin of the head. There appeared to be six lips, and there were six papillæ immediately round the mouth-opening. Circular lateral organs were located on the sides of the head at a distance from the base of the spear equal to the length of that organ. There were no eyes. The bulbous swelling forming the base of the stout spear was oblique, the dorsal side being the larger and longer. There were three ox-bow shaped guides to the spear, each one third as long as the spear itself. The spear was contained in a muscular elongated ellipsoidal swelling three times as long as the spear and half as wide as the head, in this respect somewhat resembling that of *Onyx*. From the pharyngeal swelling the tubular portion of the œsophagus, which is one fourth as wide as the neck, leads backward to the posterior muscular swelling which also resembles that of the genus *Onyx*, being one fourth as long as the neck and two thirds as wide. The coarsely granular intestine is two-thirds as wide as the body. The rectum was one and one half times as long as the anal body-diameter, and was preceded by a pre-rectum twice as long as itself. This part of the anatomy closely resembled that of *Dorylaimus*. The lateral fields were one fourth as wide as the body. The ventral excretory pore was located half-way between the nerve-ring and the cardia. There were no glands in the conoid-hemispherical tail; the terminus was rounded. I believe the vulva will be found to be central and the female sexual organs double and symmetrical.

Habitat: Virgin soil from the hills opposite Harwood, Clarence River, New South Wales, Australia. This genus combines some of the characteristics of *Tylenchus*, *Onyx*, and *Dorylaimus*.

3. Tylenchus.

A description of this genus has appeared previously in these pages, and we therefore have only to quote the same here and refer the reader to the adjacent illustrations, which convey a very good idea of the anatomy.

Transparent striated round worms, in most cases devoid of bristles or setæ, varying in length from one-third of a millimetre to three and a half millimetres, attacking the tissues of plants, or more rarely animals, by means of a pharyngial spear and sucking apparatus of the following construction :— A three-bulbed spear, capable of being thrust forth and withdrawn by appropriate muscles, is connected with a powerful median œsophageal



a, lip-region.
b, tip of spear.
c, median sucking-bulb.
d, nerve-ring.
e, excretory pore.
f, muscles for moving the spear forward.
g, posterior œsophageal swelling.
h, excretory gland.
i, hind end of spear.
j, loop in ovary.
k, right spiculum or penis.
l, muscles for opening the vulva.
m, the vulva.
n, glandular (?) bodies.
o, bursa.
p, hind end of ovary.
q, uterus containing spermatozoa and one segmenting egg at *r*.
r, segmenting egg.
s, vagina.
t, the vulva or female sexual opening.
u, blind end of posterior rudimentary ovary.
v, intestine, showing its cellular structure.
w, cross-section of an egg.
x, anus.
y, wings of the cuticle.
z, cross-section of the intestine.

Fig. 31.—Side view of the devastating eel-worm, *Tylenchus devastatrix*. I, a female worm ; II, head of the same worm more highly magnified; III, tail of a male; IV, view from below of the female sexual opening ; V, cross-section of the worm, passing through the sucking-bulb ; VI, front view of the penes and their accessory parts ; VII, cross-section through the middle of a female, showing how the body-cavity is filled completely by the ovary (*w*) and the intestine (*z*).

sucking-bulb by means of a tube whose lining is more chitinous than is usual in other Nematode genera; the medium bulb is connected with a smaller posterior bulb of much weaker construction by means of a shorter and weaker tube, which passes through the oblique nerve-ring, situated just behind the median bulb. The posterior bulb may become rudimentary, but probably never quite disappears. Lateral organs as well as visual organs are unknown in the genus. The female sexual apparatus is usually single and asymmetrical, being in that case usually straight and directed forward, and often presenting a rudimentary posterior branch, but may be double and symmetrical. In the former case the vulva is behind the middle ; in the latter case it is central. The male possesses two equal slightly arcuate spicula, and in most species a more or less well-developed bursa.

1. *Tylenchus setiferus*, n. sp. $\frac{2{\cdot}5}{1{\cdot}7}$ $\frac{10{\cdot}}{2{\cdot}}$ $\frac{15{\cdot}}{2{\cdot}3}$ $\frac{47{\cdot}}{2{\cdot}4}$ $\frac{85{\cdot}}{2{\cdot}6}$ ·7 mm. This remarkable *Tylenchus*, of which only a few males were seen, stands in great contrast with other members of this genus. The head is armed with four prominent setæ, and the bursa is of a peculiar form. The thickish cuticle is transparent, and marked with plain transverse striæ, 1·5 μ apart on the head. These are present in the outer layers of the skin as well as the inner, and the contour of the worm, as seen under the microscope, is in consequence crenate. The conoid neck terminates in a truncate head, bearing four curved and spreading submedian setæ, each about as long as the head is wide. The exact nature and form of these organs is shown in the accompanying sketch. Six spherical lips, each 2· μ high, surmount the head, and form a lip region, which is set off from the head by a slight constriction. It remained uncertain whether each lip bore a papilla. There were no eye-spots, and no lateral organs were seen. A well-developed spear, eighteen micromillimetres long, and having three bulbs at its base, each two micromillimetres in diameter, is contained in the head. The anterior part of the œsophagus is a narrow tube of glistening chitine. The median sucking-bulb, which is situated a spear-length from the three bulbs described above, is ellipsoidal in shape. Behind the sucking-bulb the œsophageal tube becomes wider, namely, one fifth as wide as the neck; half way from the median bulb to the cardia it suddenly becomes one third as wide as the neck. The

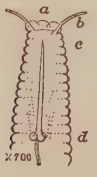


Fig. 32.—Head of *Tylenchus setifera*; *a*, mouth and lips; *b*, ciphalic setæ; *c*, stands opposite the tip of the spear; *d*, stands opposite the base of the spear.

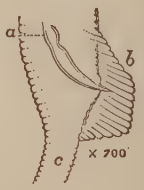


Fig. 33.—Anal region of *Tylenchus setifera*; *a*, proximal end of the right-hand spiculum; *b*, bursa (right-hand flap); *c*, beginning of the tail.

cardiac collum is distinct, and behind it the intestine becomes at once two-thirds as wide as the body. The ventral excretory pore is situated just opposite the oblique nerve-ring, which is so broad that its posterior border is situated half way between the median bulb and the cardia. The base of the tail diminishes suddenly in diameter, becoming almost at once only half as wide as at the raised anus; thenceforth it is conical. There are no caudal glands. The bursa, when seen in profile, has the form of a trapezium; its ventral margin is parallel to the body axis; its posterior margin is almost perpendicular to its ventral margin, while its anterior margin slopes forward much as usual. The two equal, elongated, arcuate, acute spicula are one and a half times as long as the anal body diameter. The spicula are supplied with accessory pieces one third as long as they themselves are. The blind end of the testicle is situated as far behind the cardia as the latter is behind the mouth.

Habitat.—This worm was found in soil from the hills opposite Harwood, Clarence River, New South Wales, Australia.

2. *Tylenchus emarginatus*, n. sp. $\frac{4\cdot}{2\cdot2}$ $\frac{12\cdot}{3\cdot}$ $\frac{21\cdot}{3\cdot4}$ $\frac{-M}{3\cdot53.}$ $\frac{77\cdot}{}$ ·6 mm. A characteristic feature of this species is the form of the bursa of the male. It forms with its posterior margin a re-entrant angle at the point where it joins the body. Consequently when the worm is viewed in profile, the tail presents a rather peculiar appearance. The striations of the cuticle are resolvable with high powers. The neck is of the usual conoid form, and is surmounted by a head six micromillimetres wide at the lips, and twelve micromillimetres wide opposite the base of the spear. The indistinct lips are three micromillimetres high. No papillæ, lateral organs or eyes were seen. The spear is twenty micromillimetres long, and is slender but well developed, and has a base composed of three distinct bulbs, each one micromillimetre in diameter. The prolate median sucking-bulb is situated at a distance behind the spear, equal to the length of the latter organ. Just behind this bulb the œsophageal tube is one fifth as wide as the neck, but gradually expands until it finally becomes one half as wide as the body. The ventral excretory pore is situated just behind the nerve-ring. The latter is twenty micromillimetres behind the median bulb. The tail is conical from the inconspicuous anus, and is pointed at the terminus. There are no caudal glands. The distance of the inconspicuous vulva from the anus is equal to two thirds the length of the tail. The eggs measure 56 μ x 16 μ, that is, are two thirds as wide as the body, and from three to four times as long as wide; they apparently become segmented while yet in the uterus. The ovary extends forward to near the base of the neck. The tail of the male resembles that of his mate in form, but is supplied with a bursa three to four times as long as the anal body-diameter, so situated as to be nearly symmetrical with respect to the anus (though, as above mentioned, it has a re-entrant angle behind the anus), and then continuing for a short distance further on the tail.

$\frac{3\cdot3}{2\cdot3}$ $\frac{10\cdot}{3\cdot}$ $\frac{16\cdot}{3.5}$ $\frac{-65\cdot}{3\cdot2}$ $\frac{78\cdot}{2\cdot}$ ·68 mm. is the formula for the female, which closely resembles the male in form. The uterus contained only one or two eggs at a time.

Habitat.—Soil, hills opposite Harwood, Clarence River, New South Wales, Australia.

3. *Tylenchus dihystera*, n. sp. $\frac{2\cdot3}{3\cdot7}$ $\frac{11\cdot}{2\cdot6}$ $\frac{17\cdot}{2\cdot9}$ $\frac{-57\cdot}{3\cdot7}$ $\frac{97\cdot5}{2\cdot3}$ ·85 mm. The number of species of *Tylenchus* the females of which possess two ovaries is comparatively few. This species is, therefore, of interest, as adding to that number, and serving to give aid in characterising the group. The coarse, plain, striations of the cuticle (2 μ) are easily resolvable with lenses of moderate power. The neck is convex-conoid anteriorly; on account of the indistinctness of the cardiac collum the length is not easily made out. The rounded head bears no setæ. The lip region is hemispherical, but it was impossible to make out the number and nature of the lips. Neither lateral organs nor eyes were seen. The three bulbs forming the base of the spear were conspicuous, the three together measuring six micromillimetres in width, occupying, consequently, one fourth the width of the corresponding part of the neck. The spear of one specimen was measured, its length being found to be 28 μ, and the breadth of its shaft 2 μ. The prolate median bulb measured 16 μ x 10 μ, and was two thirds as wide as the neck. The nature of the posterior part of the œsophagus was difficult to make out. The intestine began as far behind the ventral excretory pore as the medium sucking-bulb was in front of it. In size it was two thirds as wide as the body, and in structure coarsely and irregularly granular. The rectum equalled the anal body-diameter in length. The excretory pore

was situated behind the median bulb, at a distance varying from one to two times the length of that organ. The wings occupied a space equal to one third the width of the body, and presented longitudinal lines separated by a distance equal to one seventh the width of the body. The nerve-ring encircled the œsophagus just behind the sucking bulb. The ventral contour of the conoid tail was continuous with that of the belly, there being no bend or curve as on the dorsal side. The anus was inconspicuous. There were no caudal glands. The vulva was depressed and conspicuous, and led into a vagina, one half to two thirds as long as the body was wide, and also conspicuous. The anterior outstretched ovary reached forward nearly to the cardiac region, and the similar posterior ovary extended backward nearly to the anus. The eggs were as long as the body was wide, and two-thirds as wide as long, and were segmented while still in the uterus. Male unknown.

Habitat.—Roots of sugar-cane. Harwood, Clarence River, New South Wales, Australia.

4. *Tylenchus minutus*, n. sp. Female unknown. $\frac{2{\cdot}7}{1{\cdot}8}$ $\frac{14\cdot}{3\cdot}$ $\frac{22\cdot}{3\cdot}$ $\frac{M}{3\cdot}$ $\frac{75\cdot}{2{\cdot}4}$ ·4 mm. The markings on the skin of this tiny worm, if present at all, were so small as to escape observation with a good immersion lens. There were no hairs on the body or setæ on the head. Only the anterior third of the neck was convex-conoid. The head was almost truncate. Neither lips nor papillæ were distinctly seen. There were no eyes, likewise no lateral organs. The spear, though minute, was perfect in form, having three bulbs at its base; its length was somewhat greater than the width of the head measured opposite its base. The ellipsoidal median sucking-bulb was half as wide as the neck, and was situated at the termination of the anterior two fifths of the neck. The tube leading from the bulb was at first only one fourth as wide as the neck, but in the posterior fifth of the neck was swollen to twice that width. As is usual in *Tylenchus*, the cardiac collum was indistinct. The intestine was half as wide as the body and coarsely granular. The ventral excretory pore was situated half way between the sucking-bulb and the intestine. The oblique nerve-ring encircled the œsophagus at a distance behind the sucking-bulb equal to the length of that organ. The tail was conical from the slightly-elevated anus, and was not supplied with a spinneret or with glands. The bursa extended along the tail a distance equal to three times the anal body-diameter and along the body in front of the anus a distance half as great as on the tail, and was in every way small and inconspicuous, its contour when seen in profile not reaching to the ventral contour of the worm. The two equal linear slightly arcuate spicula were fully twice as long as the anal body-diameter; their proximal ends were not contrasted in any way with the shafts. The very inconspicuous accessory pieces were half as long as the spicula, close and parallel to which they were situated.

Habitat.—Roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

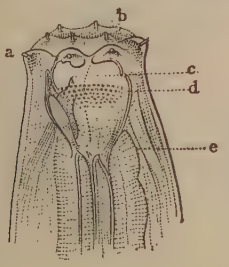
5. *Tylenchus uniformis*, n. sp. $\frac{1\,8}{1{\cdot}9}$ $\frac{?}{?}$ $\frac{?}{?}$ $\frac{45}{-45\cdot-}$ $\frac{88\cdot}{2{\cdot}2}$ ·63 mm. The transverse striæ of the cuticle were so inconspicuous as to be resolvable only with good lenses of high power. There were no hairs or cephalic setæ. The lips were indistinct and the lip region was not, as is often the case in this genus, set off by a constriction. There were no eyes. The slender spear was one and a half times as long as the head was wide. The anterior part of the œsophagus was about half as wide as the corresponding part of the neck; the median bulb, which was located at the beginning of the

second third of the œsophagus was a mere slight expansion two fifths to one half as wide as that part of the neck; the tube connecting it with the expanded posterior fourth of the œsophagus was one fourth as wide as the neck; at its posterior extremity the œsophagus was half as wide as the base of the neck. The intestine was half as wide as the body, and displayed numerous large refracting granules. The rectum appeared to be equal to the anal body-diameter in length. The ventral excretory gland appeared to be located alongside the posterior swelling of the œsophagus; the ventral pore, its outlet, was situated just behind the nerve-ring, *i.e.*, in advance of the swelling just mentioned. The oblique nerve-ring encircled the œsophageal tube at the beginning of its fourth fifth. There were no glands in the tail, which was conical from the inconspicuous anus. The depressed vulva was easily to be seen. The posterior branch of the sexual organs was rudimentary, and extended only half way to the anus. The blind end of the anterior branch lay as far behind the cardia as the nerve-ring was in front of it. $\frac{1{\cdot}8}{1{\cdot}2}$ $\frac{10{\cdot}}{2{\cdot}5}$ $\frac{18{\cdot}}{2{\cdot}6}$ $\frac{-M}{2{\cdot}7}$ $\frac{90{\cdot}}{1{\cdot}8}$ ·64 mm. The tail of the male resembled that of his mate in form, but the anus was elevated and easily seen. No papillæ were seen. The bursa extended along the anterior fourth of the tail and equally far in front of the anus; it was so narrow as not to show beyond the ventral contour of the body when the worm was viewed in profile, and was, therefore, quite inconspicuous. The two equal elongated cuneiform spicula were twice as long as the anal body-diameter, and were arcuate in the distal two thirds, the proximal third being enlarged. The very inconspicuous accessory pieces were one fourth as long as the spicula, to which they were very close. The testicle extended forward to a point as far behind the cardia as the mouth was in front of it.

Habitat.—Found in soil about the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

4. Mononchus.

This genus includes at present nearly twenty species, none of which are parasitic. All feed on the roots or other tissues of plants. I have reason to believe they at times do considerable damage, more particularly to tender



a, papilla of the outer row.
b, papilla of the inner row.
c, dorsal tooth.
d, rasp-like teeth on inner wall of the pharynx.
e, beginning of the œsophagus.

Fig. 34.—Head of *Mononchus digitarus*, highly magnified.

seedlings. I have washed as many as three hundred of these worms from a single bunch of celery. The anatomy of a typical female is well shown in the adjacent wood-cut. The males are rare, and comparatively little is known about them.

1. *Mononchus intermedius*, n. sp. $\frac{2{\cdot}5}{2{\cdot}4}$ $\frac{7{\cdot}4}{2{\cdot}4}$ $\frac{24{\cdot}}{2{\cdot}8}$ $\frac{'61}{3{\cdot}3}$ $\frac{94{\cdot}}{24}$ 1·93 mm. As in all other known species of *Mononchus*, the cuticle was devoid both of hairs and striations. The cylindroid neck terminated in a truncate head without setæ, but bearing six lips each with two papillæ as usual. Elongated oval markings placed transversely on the head just behind the base of the lips

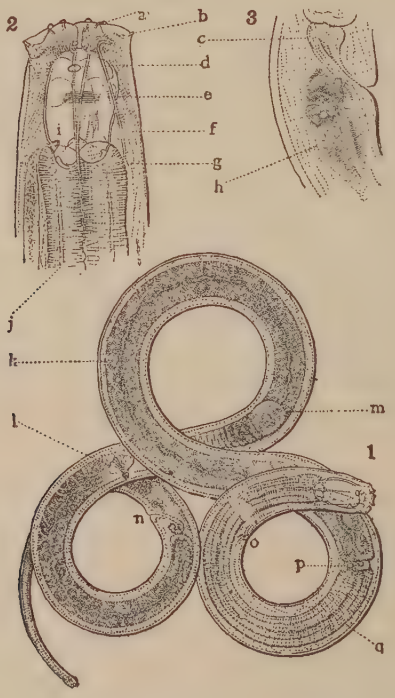


Fig. 35.—Anatomical details of *Mononchus gymnolaimus*: 1, female worm; 2, head of the same more highly magnified; 3, anal region.

a, papilla of the inner row.
b, papilla of the outer row.
c, rectum.
d, lateral organ.
e, striation of inner wall of pharynx.
f, pharyngeal muscles.
g, beginning of œsophagus.
h, caudal glands.
i, dorsal tooth.
j, œsophagus.
k, intestine.
l, vagina.
m, flexure in ovary.
n, anus.
o, excretory pore (?)
p, cardiac constriction or collum.
q, œsophgus.

served to represent the lateral organs; these were half as wide as the base of the nearest lip. This species agrees with all others of the genus in having no eyes. The pharynx was long and goblet-shaped, being half as long as the head is wide, and bearing a moderate-sized dorsal tooth two thirds the way from the base to the lips. In the neighbourhood of the nerve-ring the œsophagus is only half as wide as the neck, but near the pharynx it is

somewhat wider, and again posteriorly it becomes three fifths as wide as the body. The posterior part of the œsophagus appears to be coarser in structure than the anterior half; in all parts the lining appeared as three distinct double lines. The olive-coloured intestine, which was separated from the œsophagus by a distinct constriction, was three fourths as wide as the body, and rather indistinctly tessellated; its commencement was marked by the presence of a pseudo-bulb, this appearance being brought about by the transparent nature of the walls in the cardiac region. The intestine ended in a rectum whose length equalled that of the anal body-diameter. The ventral excretory pore, or what appeared to be such, was located just behind the nerve-ring. The lateral fields were one-fourth as wide as the body. The nerve-ring encircled the œsophagus squarely as is always the case in this genus. Caudal glands were present in the conical and arcuate tail, which ended in an inconspicuous and almost pointed spinneret. The anus was depressed and conspicuous. The conspicuous vulva led into a vagina half as long as the body was wide. The reflexed portion of the ovaries extended half-way back to the vulva.

a, mouth.
b, labial papilla.
c, lateral organ.
d, dorsal tooth.
e, excretory pore.
f, nerve-ring.
g, pharynx.
h, pharyngeal muscles.
i, *j*, œsophagus.
k, cardiac region.
l, intestine.
m, labial papilla.
n, lateral organ.
o, ovum.
p, dorsal tooth.
q, pharynx.
r, egg with shell.
s, vulva.
t, blind end of posterior ovary.
u, bend in ovary.
v, anus.
w, three caudal glands.
x, one of two papillæ on the end of tail.
y, outlet for caudal glands.

Fig. 36.—I, female *Mononchus longicaudatus;* II, side view of head of same worm; III, ventral view of head of same worm; IV, end of tail of same worm.

Habitat.—About roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

2. *Mononchus similis*, n. sp. $\frac{3{\cdot}3}{3{\cdot}}$ $\frac{8{\cdot}}{3{\cdot}5}$ $\frac{24{\cdot}}{4{\cdot}1}$ $\frac{'58}{4{\cdot}5}$ $\frac{86.}{2{\cdot}4}$ 1·83 mm. As usual the skin was without hairs or markings of any kind. The cylindroid neck ended in a truncate head without setæ, but with the usual two rows of labial papillæ. The lateral organs were not seen unless they be represented by transverse slits near the base of the outside lateral papillæ. The pharynx was three fifths as wide as the head, and nearly one and one half times as long as wide, and contained a single small dorsal tooth at the base. In form the pharynx was triquetrous, and ribbed longitudinally, and had the middle half of the lateral walls covered with teeth like those of a file. The œsophagus was anteriorly one half, but posteriorly two thirds, as wide as the neck, and had a coarsely-radiated structure; its lining appeared as a triple line when seen in optical section. Cardiac collum shallow but distinct, pseudo-bulb faint. The olive-coloured intestine was three fourths as wide as the body, and the granules contained in its cells were so arranged as to give rise to a tessellation; this made it easy to count the cells, the result showing that it took about fifteen of them to build the circumference. The rectum was three fourths as long as

the anal body-diameter. A ventral pore, presumably the outlet of the ventral gland, occurred just behind the nerve-ring. As usual in *Mononchus*, the nerve-ring encircled the œsophagus rather squarely. The tail was arcuate and conoid from the conspicuous depressed anus, and ended in a blunt spinneret one eighth to one sixth as wide as the base. The spermatozoa were arranged in a ball in the uterus. The ovaries reached half-way back to the vulva.

Habitat.—Roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

5. Neonchus, new genus.

1. *Neonchus longicauda*, n.sp. $\frac{1{\cdot}6}{1{\cdot}7}\ \frac{7{\cdot}5}{2{\cdot}4}\ \frac{16{\cdot}}{2{\cdot}7}\ \frac{50{\cdot}}{3{\cdot}}\ \frac{64{\cdot}}{1{\cdot}7}$ ·7 mm It is possible that this worm stands in a position between *Mononchus* and the spear-bearing genera. Only two rather immature females having been seen, it is not possible to make positive statements with regard to affinities. The skin bears a few hairs, and is marked by transverse striæ resolvable with high powers. With lenses of the highest power, each striation is resolvable into a row of dots. A rounded head surmounts the conoid neck. Ten spreading setæ, each two fifths as long as the head is wide, are arranged in the usual manner on the margin of the head. Four submedian subcephalic setæ, a trifle longer than those on the margin of the head, are found half-way between the lateral organs and the base of the pharynx. Small knob-like papillæ occur on the front of the head. The lateral organs resemble those of *Plectus*, being unclosed circumferences one fourth as wide as the head, situated opposite the middle of the pharynx. There are no eyes. The prismoid pharynx is about one fifth as long as the neck, and one seventh as wide, and is strongly lined with chitine. The dorsal wall is prolonged into a tooth or spear, and this organ seems to have guides somewhat after the manner of *Onyx*. *Neonchus* shows another resemblance to *Onyx* in the formation of the œsophagus, which is at first tubular, and only one-third as long as the corresponding part of the neck, but expands in the posterior fourth to form an elongated swelling two-thirds as wide as the base of the neck. Where the œsophagus receives the pharynx, it is also somewhat enlarged. The lining of the œsophagus appears as a single distinct line when seen in optical section. The cardiac collum is deep and very distinct. The irregularly granular intestine becomes at once three fourths as wide as the body. The rather small, shallow cardia can be distinctly seen. The rectum equals the anal body-diameter in length, or somewhat exceeds it. The nature of the ventral gland, and of the lateral fields, remains unknown. The nerve-ring surrounds the œsophagus almost squarely a trifle in front of the middle of the neck. The conoid tail tapers more rapidly near

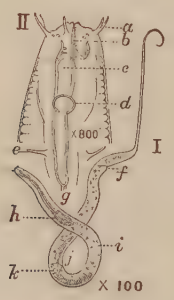


Fig. 37.—*Neonchus longicauda*: I, a female worm; II, head of the same worm more highly magnified; *a*, cephalic setæ; *b*, tooth or rudimentary spear; *c*, pharynx; *d*, lateral organ; *e*, subcephalic seta; *f*, anus; *g*, base of the pharynx; *h*, posterior swelling of the œsophagus; *i*, intestine; *j*, vulva; *k*, either spermatozoa or immature ova.

the anus than elsewhere. The depressed anus is distinctly to be seen. There are no caudal glands. Possibly the tail is prehensile. The terminus is one sixteenth as wide as the base of the tail. I saw only immature females, and can only surmise that their sexual organs are double and symmetrical, and not reflexed (– ♀ –).

Habitat.—Soil about the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia. Also about the roots of moss near Maclean, on the same river.

6. Chromadora.

1. *Chromadora minima*, Cobb. $\frac{2{\cdot}8 \quad ? \quad 17{\cdot} \quad 45{\cdot} \quad 87{\cdot}}{2{\cdot}5 \quad ? \quad 3{\cdot}9 \quad 4{\cdot}4 \quad 2{\cdot}3}$ ·51 mm, The transverse striæ are resolvable, with high powers, into rows of dots. The hairs on the body, if any be present, must be very inconspicuous. The neck was conoid, more especially in the anterior part. The head was somewhat truncate, and bore at least six small, rather forward-pointing setæ, perhaps one sixth as long as the head was wide. The rather transparent lips bore papillæ, probably twelve. The lateral organs were placed just behind the base of the pharynx; the right was a left-handed spiral of two

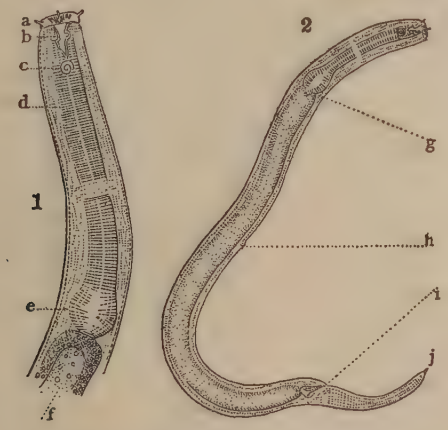


Fig. 38.—*Chromadora minima*, magnified.

a, one of the cephalic setæ.
b, pharynx.
c, spiral lateral organ.
d, œsophagus.
e, posterior œsophageal bulb.
g, cardiac collum,
h, vulva.
i, anus.
j, spinneret

and a fourth turns, and the left was a similar right-handed spiral. The worm has no eye-spots. The anterior part of the pharynx was cyathiform, and presented the usual twelve chitinous ribs; the posterior part appeared sigmoid when seen in profile. The tooth was exactly like that of the Fiji worm (*C. minima*). The œsophagus was about half as wide as the neck, though where it received the pharynx it was somewhat larger; at the posterior extremity it enlarged to form a prolate bulb four fifths as wide as the base of the neck, and containing an elongated internal chitinous arrangement. The lining of the œsophagus was plainly visible, and appeared as two slightly sinuous lines. The rather thick-walled intestine was two

thirds as wide as the body, and was separated from the œsophagus by a distinct constriction; it ended in a rectum of the same length as the anal body-diameter. A ventral gland lay just behind the cardiac constriction, but all its parts were difficult to make out; the location of the pore, its outlet, was a little behind the ring, the ampulla being roundish. The tail was conoid from the rather conspicuous anus, and ended in an apiculate spinneret one fourth as wide as the body at the anus. The conspicuous shining vulva was slightly depressed. The two ovaries were outstretched (— ♀ —), the eggs being three times as long as the body was wide, and only about half as wide as long. The female is shown in the adjacent figures.

Habitat.—Soil about the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia. Found previously (1891) in Fiji, about the roots of banana plants. The Fiji worms were immature, and in consequence the descriptions imperfect. I have observed this worm also at Moss Vale, New South Wales.

7. Chaolaimus, new genus.

1. *Chaolaimus pellucidus*; n. sp. $\frac{4\cdot}{2\cdot}$ $\frac{11\cdot}{4\cdot}$ $\frac{23\cdot}{4\cdot1}$ $\frac{58\cdot}{4\cdot7}$ $\frac{95\cdot}{3\cdot1}$ ·64 mm. At first sight this worm has the appearance of a *Tylenchus*. It does not, however, belong to that genus, but, in all probability, to a new genus. Only one specimen was seen, and that an immature moulting female, so that many important parts of the anatomy remain unknown. The cuticle appears to be without striæ, as none were seen with a $\frac{1}{12}$ homogenous immersion lens. There were no hairs on the body. Posteriorly the neck is cylindrical, though the anterior third is convex-conoid, and ends in a truncate head, bearing six papilla-like setæ on the margin of the head. The lips, if they be present, must be very flat and inconspicuous. Neither eyes nor lateral organs were seen. The pharynx was difficult to understand. The posterior half was simple enough, merely cylindroidal and one fifth as wide as the head, and having two chitinous thickenings like knobs at the base; this part was strongly lined with chitine. The anterior half of the pharynx was composed of numerous pieces of chitine arranged irregularly as if they were the fragments of broken pharyngeal lining. The whole pharynx was enclosed in what appeared like an ellipsoidal bladder, twice as long as wide, and three fourths as wide as the head. All these observations are made of uncertain value because of the worm being in process of moulting the skin, and with it, of course, the pharyngeal lining. The cardiac collum was indistinct. The intestine was three fourths as wide as the body, and presented irregular granules. The ventral excretory pore was situated somewhat behind the nerve-ring, or, more accurately, at the end of the second third of the neck. The blunt tail was convex-conoid from the conspicuous depressed anus. The vulva was inconspicuous. The sexual organ appeared to be single, to extend forward (♀), and the reflexed part to extend back past the vulva, half-way to the anus. The only egg seen was twice as long as the body was wide, and one fourth as wide as long.

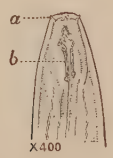


Fig. 39.—Head of *Chaolaimus pellucidus*

Habitat.—Roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

8. Monhystera.

So far as known the worms classed under this head are harmless to man. They inhabit the soil and the sea, and appear to feed upon microscopic organisms. A good idea of the anatomy will be gained by consulting the accompanying figures and those of the first species described below.

1. *Monhystera rustica*, Bütschli. $\frac{\cdot 9}{2\cdot 5}$ $\frac{11\cdot}{3\cdot 8}$ $\frac{18\cdot}{4\cdot 2}$ $-\frac{60\cdot}{4\cdot 5}{}^{28}$ $\frac{76\cdot}{2\cdot 9}$ ·5 mm. The cuticle is marked by striæ, resolvable with immersion lenses. A few hairs, about one eighth as long as the body is wide, are found here and there. The nearly cylindroid neck terminates in a truncate head, bearing near its margin ten spreading setæ, arising opposite the base of the pharynx, each about one fourth as long as the head is wide, one of each submedian pair being somewhat shorter that its mate. There are six indistinct papillæ inside the row of setæ. Ths circular lateral organs are one fourth as wide as the neck, and are placed at a distance from the anterior extremity equal to three or four times the depth of the simple, somewhat cup-shaped pharynx. This latter is one third as wide as the head, and leads into a cylindroid œsophagus nearly two thirds as wide as the neck, and presents a very slight expansion in front of the distinct cardiac constriction. For some distance behind the pharynx the œsophagus is very transparent. The lining of the œsophagus when seen in optical section is more or less sinuous. At the

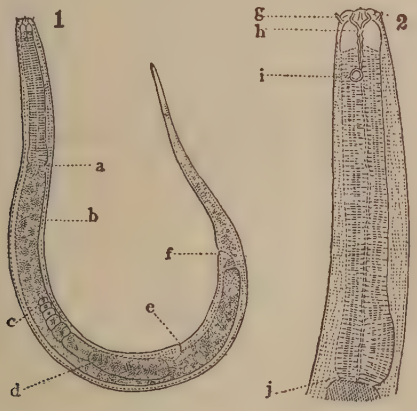


Fig. 40.—*Monhystera rustica*, magnified. 1, Female worm; 2, head and neck of the same worm more highly magnified; *a*, cardiac collum; *b*, intestine; *c*, blind end of ovary; *d*, egg; *e*, vulva; *f*, anus; *g*, one of the cephalic setae; *h*, base of the pharynx; *i*, lateral organ; *j*, cardiac collum.

beginning, opposite the cardia, the intestine is somewhat transparent, giving rise at first to the impression that some gland-like organ is present here, but careful examination serves to dispel the deception. The intestine is two-thirds as wide as the body, and is composed of cells indistinctly to be seen on account of the multitude of granules with which they are filled. The transparent rectum is conoid, and its length is equal to that of the anal

body-diameter. Nothing was learned concerning either the ventral excretory organs or the lateral fields. The nerve-ring is situated near the middle of the neck, and encircles the œsophagus somewhat squarely. The tail is conoid to the swollen terminus, where it is one sixth as wide as at the base. There are caudal glands and a spinneret. The vulva is depressed. The eggs are twice as long as the body is wide, and one fourth as wide as long, and are probably deposited before segmentation begins.

Habitat.—About roots of moss, Maclean, Clarence River, New South Wales, Australia. This now well-known species is found also in Fiji. I am able here to add considerably to a knowledge of its anatomy.

2. *Monhystera insignis*, n. sp. $\frac{1{\cdot}3}{2{\cdot}5}\ \frac{10{\cdot}}{3{\cdot}}\ \frac{22{\cdot}}{3{\cdot}2}\ -\frac{75}{3\ 6}\ \frac{83{\cdot}}{2{\cdot}9}$ ·85 mm. The transverse striæ were so fine as to be barely resolvable with a good one twelfth inch homogenous lens. A few hairs were scattered here and there on the worm; these were one fourth as long as the body was wide. The nearly cylindrical neck terminated in a truncate head bearing twelve spreading setæ, each about half as long as the head was wide, though the members of the submedian pairs were not quite equal in length; these setæ were attached just behind the transparent lips, of which there appeared to be three. Each of the six papillæ found on the lips bore a minute bristle. The circular lateral organs were one fifth as wide as the head, and were located at a distance from the anterior extremity equal to twice the width of the head. There were no eyes. The pharynx consisted of an oblate mouth cavity one half as wide as the head, followed by a narrower conoid part; the length of the whole was equal to the width of the head. The width of the nearly cylindrical œsophagus was half as great as that of the neck; its lining appeared as a single distinct line. The granular intestine, which was two thirds as wide as the body, was separated from the œsophagus by a deep and distinct constriction, and ended in a transparent rectum nearly twice as long as the anal body-diameter. The tail, which was conoid from the depressed anus, contained caudal glands, and ended in a blunt apiculate spinneret one third as wide as the body at the anus.

Habitat.—Found about the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

3. *Monhystera pratensis*, n. sp. $\frac{\cdot8}{2{\cdot}}\ \frac{10{\cdot}}{2{\cdot}9}\ \frac{22{\cdot}}{3{\cdot}3}\ -\frac{60{\cdot}}{3{\cdot}8}\ \frac{88{\cdot}}{2{\cdot}3}$ 1·mm. The transverse striæ of the cuticle are resolvable with high powers. The hairs, which occur throughout the length of the worm, are easily seen, as they are one fourth as long as the body is wide. The neck was cylindrical and the head truncate. The ten cephalic setæ were about half as long as the head was wide, and were arranged in the usual manner, the submedian being sub-equal. The lip-region was transparent, and its details difficult to determine. If any papillæ were present they must have been very inconspicuous. The circular lateral organs were one fourth as wide as the head, and were located at a distance from the anterior extremity equal to the width of the head. There were no eyes. The cylindrical œsophagus, which, though pretty uniformly three fifths as wide as the neck, was slightly swollen posteriorly, was separated from the intestine by a deep and distinct constriction. The lining of the œsophagus when seen in optical section appeared as a distinct single line. The transparent finely granular intestine was three fourths as wide as the body, and presented no signs of tessellation. The rectum somewhat exceeded the anal body-diameter in length. The nerve-ring was a trifle oblique. The tail was conical from the conspicuous depressed anus to the blunt spinneret, which was one eighth as wide as the base of the tail. The

vulva was elevated and conspicuous. The single egg seen in the uterus was rectangular, being as long as the body was wide, and four fifths as wide as long; it was unsegmented. The spermatozoa were one half as wide as the uterus. The ovary appeared to extend about half-way to the cardia.

Habitat.—Found in soil about the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

4. *Monhystera Australis*, n. sp. $\frac{1{\cdot}1 \quad 10{\cdot} \quad 21{\cdot} \quad -80{\cdot} \quad 85{\cdot}}{2{\cdot}4 \quad 3{\cdot} \quad 3{\cdot}2 \quad 2{\cdot}8 \quad 2{\cdot}1}$ ·85 mm. The information I have concerning the anatomy of this species is very meagre. The most striking feature is the nearness of the vulva to the anus. The cephalic setæ are well developed. The lip region is transparent, and encloses an oblate cavity half as wide as the head. I am uncertain about the location and size of the lateral organs; they were probably circles one fourth as wide as the neck, located at a distance from the anterior extremity equal to one and one half times the width of the head. The anterior part of the œsophagus was three fifths as wide as the neck; posteriorly, however, it became two thirds as wide as the neck. The dark-coloured intestine was three fourths as wide as the body, and was marked off from the œsophagus by a distinct constriction; its cells were easily made out on account of the transparency of the walls. The conoid rectum considerably exceeded the anal body-diameter in length. The body diminished more rapidly in size from the vulva backward. From the conspicuous elevated anus the tail was conoid to the somewhat conical and apiculate spinneret.

Habitat.—Soil from hills opposite Harwood, on the Clarence River, New South Wales, Australia.

9. Alaimus.

1. *Alaimus minor*, n. sp. $\frac{\cdot5 \quad 14{\cdot} \quad 33{\cdot} \quad 49{\cdot} \quad 96{\cdot}}{1{\cdot} \quad 2{\cdot}5 \quad 2\ 9 \quad 2{\cdot}9 \quad 1{\cdot}1}$ ·64 mm. The formula represents pretty much all that was discovered concerning this new species. The œsophagus was pretty uniformly one half to two thirds as wide as the neck. The sexual organ appeared to be single, and to extend backward; it remained uncertain whether it was reflexed. I am not positive about the length of the tail as expressed in the formula. Tail conoid.

Habitat.—Soil from hills opposite Harwood, Clarence River, New South Wales, Australia.

10. Bastiana.

1. *Bastiana Australis*, n. sp. $\frac{? \quad ? \quad 23{\cdot} \quad M \quad 85{\cdot}}{\cdot6 \quad ? \quad 1{\cdot}5 \quad 1{\cdot}6 \quad 1{\cdot}5}$ ·95 mm. Female unknown. The neck was cylindrical posteriorly, but the anterior half was conoid. The rounded head bore the usual number of setæ, each of these being about as long as the head was wide. The œsophagus was of about the same shape as the neck, being from one third to one half as wide. The cardiac collum was distinct. The intestine was three fourths as wide as the body. The tail was conoid. The linear arcuate acute spicula were one and one-half times as long as the anal body-diameter. I think there were two testicles (—M—). The row of ventral accessory organs extended forward to the middle of the neck; the distance separating these organs one from another was about equal to half the width of the body.

Habitat.—Virgin soil from hills opposite Harwood, Clarence River, New South Wales, Australia.

11. Cephalonema, new genus.

1. *Cephalonema longicauda*, n. sp. This peculiar worm belongs to a new and very distinct genus. I have thus far seen two species—the present, on the Clarence River, and a second at Moss Vale, N.S.W. Both were, however, immature, so that much remains to be learned about the nature of the sexual organs. Nor is this all; for though I have been able to give in the accompanying figure a good idea of the form of the head and pharynx I can offer no explanation of the uses of the various organs or structures I have pictured. The worms at first sight appear to belong to *Dorylaimus*, another genus of free-living nematodes, but a short examination is sufficient to dispel this illusion. Two specimens of the present species gave the following measurements:—$\frac{? \quad ? \quad 18 \quad ? \quad 75}{? \quad ? \quad 2{\cdot}6 \quad ? \quad 1{\cdot}5}$ ·44 mm. and $\frac{4{\cdot}8 \quad 9{\cdot}6 \quad 20 \quad ? \quad 76}{1{\cdot}7 \quad 1{\cdot}8 \quad 1{\cdot}9 \quad 1{\cdot}9 \quad 1{\cdot}3}$ 1·1 mm. Both were young, and as yet showed no traces of sexual organs. The body wall was thick, like that of various species of *Dorylaimus*. No markings were seen on the cuticle. The neck was sub-cylindroid, and was capped by a somewhat rounded head set off by a distinct constriction. There were four very short submedian setæ, and these were the only hairs seen on the worm. The somewhat hemispherical lip region was evidently composed of six connate lips, bearing twelve papillæ, arranged in two rows somewhat like those on the head of *Dorylaimus*. I saw no lateral organs, and there were certainly no eyes. The long and narrow pharynx measured from one sixth to one fourth as wide as the head, and reached half-way to the nerve-ring, and contained near the lips an organ that resembles the thumb-shaped tooth sometimes seen in the anterior part of the pharynx of *Diplogaster*. In the anterior part the œsophagus was one half as wide as the neck; in the posterior third, however, it was widened after the manner of the œsophagus in *Dorylaimus* and *Onyx*. When seen in optical section the lining of the œsophagus appeared as a single line. The irregularly granular intestine was separated from the œsophagus by a rather indistinct constriction, and was narrower than the œsophagus, being only half as wide as the body. The rectum was equal in length to the anal body-diameter; there was no prerectum, as in *Dorylaimus*. The nerve-ring, which was two thirds as wide as the neck, encircled the œsophagus obliquely. The tail was conical from the slightly-depressed anus. There were no caudal glands, and the terminus was hair-fine.

Fig. 41.—Head of *Cephalonema longicauda*; *a*, labial papillæ; *b*, one of the four submedian cephalic setæ; *c*, horny processes in the mouth, of unknown significance; *d*, long tubular pharynx.

Habitat.—Found about the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

12. Plectus.

The nematodes belonging to this genus are harmless to crops. They are found both in the soil and on the surface of plants, and are never parasitic. They appear to feed upon microscopic organisms. They are active little worms, having the power to retain life after having been preserved for many years in a dry state. The characteristic features of the genus are unmistakable, and no one will ever, having once carefully examined a specimen, be at a loss to recognise similar worms in future. The long two-chambered pharynx, the œsophagus with a single well developed cardiac bulb, and the well developed spinneret are among the most striking features of the anatomy.

1. *Plectus parietinus*, Bastian $\frac{7\cdot8}{3\cdot9}$ $\frac{?}{?}$ $\frac{22\cdot}{5\cdot6}$ $\frac{50\cdot}{6\cdot9}$ $\frac{89\cdot}{31}$ 1·13. This worm, of which only two females were seen, is probably the *parietinus* of Bastian.

2. *Plectus minimus*, n. sp. $\frac{?}{?}$ $\frac{15\cdot}{3\cdot3}$ $\frac{30\cdot}{3\cdot6}$ $\frac{59\cdot}{3\cdot5}$ $\frac{90\cdot}{2\cdot2}$ ·33 mm. Although we are not in possession of very full details with regard to the anatomy of this species, there will, I think, be no difficulty in recognizing the species in future. The small size, the long neck and tail, and comparative slenderness are all striking characteristics. The pharynx was of the same form as that characteristic of the genus *Plectus*, and appeared to occupy two fifths of the space between the anterior extremity and the nerve-ring. The œsophagus was about half as wide as the neck, and ended in an elongated ellipsoidal bulb (three fourths as wide as the base of the neck), containing a distinct valve and connected with the intestine by a tubular cardia as long as the bulb itself. The intestine was about two thirds as wide as the body, and ended in a rectum one and one-half times as long as the anal body-diameter. The body diminished in size rapidly in the neighbourhood of the anus, the tail being conoid to the apiculate spinneret, which was one third as wide as that portion of the body nearest the anus. The single mature egg was four times as long as the body was wide, and from five to six times as long as wide; it was still unicullular, segmentation not having yet begun. The form of the sexual organs remains undetermined.

Habitat.—Soil from hills opposite Harwood, Clarence River, New South Wales, Australia.

3. *Plectus pusillus*, n. sp. $\frac{7\cdot6}{2\cdot9}$ $\frac{17\cdot}{3\cdot3}$ $\frac{29\cdot}{3\cdot9}$ $\frac{52\cdot^{25}}{4\cdot8}$ $\frac{90\cdot}{2\cdot6}$ ·43 mm. The plain transverse striæ were visible only with high powers of the microscope. No hairs were seen on the body. Posteriorly the neck was cylindroid, but in the anterior fourth it was convex-conoid. The truncate head bore four spreading setæ attached a little behind the base of the lips, each one fourth as long as the head was wide. There were six lips, as is usual in *Plectus*, and each of the six bore a papilla. The lateral organs were unclosed circumferences one fourth as wide as the head, located opposite the middle of the anterior half of the pharynx. This latter was two-chambered, the two chambers being of equal length; the anterior one was prismoid, one-fourth as wide as the head, and not expanded near the lips, while the posterior one was enclosed in a tube resembling the succeeding part of the œsophagus in size and appearance. There were no eyes. The anterior half of the œsophagus was two thirds as wide as the neck, but narrowed in the neighbourhood of the nerve-ring to one third as wide as the corresponding part of the neck. The cardiac bulb forming the posterior extremity of the œsophagus was broadly fusiform, and two thirds as wide as the base of the neck; it contained a distinct valve in front of its middle point, and was

connected with the intestine by an almost tubular cardia, extending into the cardiac cavity a distance equal to one fifth the length of the bulb. When seen in optical section the lining of the cardia appeared as a single distinct straight line. Corresponding with the nature of the cardia, the cardiac collum was very unusually broad and distinct. The intestine was three fourths as wide as the body, and, though granular, showed no traces of tessellation. The ventral gland lies in front of the cardia, and the pore, its outlet is located just behind the somewhat oblique nerve-ring. This latter is twice as broad as the œsophagus at the point encircled. The tail is conoid from the inconspicuous anus, and ends in a rounded apiculate spinneret one third as wide as the body at the anus. The vulva is elevated, and comparatively conspicuous. The thin-shelled eggs are more than twice as long as the body is wide, and are about one third as wide as long.

Habitat.—Soil about the roots of moss, Maclean, Clarence River, New South Wales, Australia.

4. *Plectus intermedius*, n. sp. $\frac{7{\cdot}2}{3{\cdot}2}$ $\frac{13{\cdot}}{3{\cdot}5}$ $\frac{24{\cdot}}{4{\cdot}2}$ $\frac{23}{'50'}$ $\frac{87{\cdot}}{4{\cdot}4}$ $\frac{}{2{\cdot}8}$ 1 mm. The striæ of the cuticle are resolvable with moderate powers of the microscope. Very short hairs occur on the body. The conoid neck is surmounted by a rather rounded head. Four submedian, widely spreading setæ, each one fifth as long as the head is wide, occur at the base of the lips. These latter are six in number, are small, inconspicuous and hemispherical, and bear very inconspicuous papillæ. The lateral organs are unclosed circumferences, one seventh as wide as the head, and are located as far behind the cephalic setæ as the latter are behind the anterior extremity. There are no eyes. The entire pharynx is three tenths as long as the neck, its anterior chamber being half as long as the posterior. Near the mouth the anterior chamber is nearly half as wide as the head, but soon becomes narrower. The posterior part of the pharynx resembles the succeeding part of the œsophagus, but is easily distinguished by the presence in it of three arcuate expansions of the lining, which together form an arrangement having a fusiform contour. The tube of the œsophagus is about half as wide as the neck, and ends in pyriform or ellipsoidal bulb, two thirds as wide as the body, and containing a very distinct valvular apparatus half as wide as the bulb itself. The lining of the œsophagus, when seen in optical section, appears as a single line. The thin-walled and colourless intestine, which is marked off from the œsophagus by a deep and distinct constriction, is two thirds as wide as the body. Its cells contain small granules, not having any apparent definite arrangement. There is a very distinct cardia, half as long as the bulb, so large as to nearly fill the cardiac cavity. The rectum was somewhat longer than the anal body-diameter. The ventral excretory pore was located nearly opposite the nerve-ring. This latter encircled the œsophagus squarely. The conoid tail tapered from in front of the inconspicuous anus to the rounded apiculate spinneret, one fourth as wide as that portion of the body near the anus. The rather inconspicuous vulva was a depressed transverse slit, one third as long as the body was wide, and led into a vagina one half as long as the body was wide. The dark and conspicuous thin-shelled eggs were from once and one half to twice as long as the body diameter, and from one third to two thirds as long as wide. The reflexed ovaries reached three fourths the distance back to the vulva. Near the blind ends of the ovaries the ova were arranged in several rows—not single file.

Habitat.—About the roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

5. *Plectus cephalatus*, n.sp. $\frac{9\cdot}{5\cdot4}$ $\frac{14\cdot}{6\cdot3}$ $\frac{24\cdot}{7\cdot3}$ $\frac{'49\cdot''}{8\cdot5}$ $\frac{87\cdot}{3\cdot8}$ ·4 *mm.* This active and interesting little species adds another to the little group of *Plecti* having expansions of the cuticula in the neighbourhood of the head. These expansions, as well as all the rest of the cuticula, are marked with plain transverse striæ resolvable with high powers. The hairs on the body are few, but they are conspicuous. The neck is conoid, and the head truncate. There are four submedian, forward-pointing, cephalic setæ, each two thirds as long as the head is wide; these are situated on the margin of the head. The expanded lip region is composed of six prominent lips, each of which seems to bear a papilla. The lateral organs are unclosed circumferences, one third as wide as the head, exclusive of the cuticular expansions: regarded as spirals, the left is a right-handed spiral, and the right a left-handed spiral.

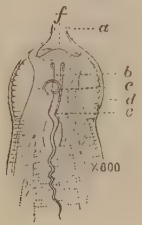


Fig. 42.—Head of *Plectus cephalatus*. *a*, four processes of the cuticular expansion *d* which pass forward and surround the mouth; *b*, anterior pharyngeal chamber; *c*, spiral lateral organ; *d*, expansion of the cuticle on the head; *e*, base of the anterior pharyngeal chamber.

There are no eyes. The two-chambered pharynx extends half-way to the nerve-ring, the anterior prismoid chamber, which is almost twice as long as the posterior, being one fourth as wide as the head; the posterior chamber is of the form usual in *Plectus*, and resembles the succeeding part of the œsophagus. At first the œsophagus is half as wide as the corresponding part of the neck, but it diminishes in its posterior part to one fourth as wide as the base of the neck, though it finally expands into a pyriform bulb, which includes the conspicuous cardia and is one half as wide as the neck. The lining of the œsophagus is plainly to be seen. The rather thick-walled intestine is three fourths as wide as the body, and is lined with chitine. The cardia, as indicated above, is very long and large. The rectum equals the anal body-diameter in length. The ventral excretory pore is situated just behind the nerve-ring. The two wings of the cuticula are separated by a distance equal to one ninth of the width of the body. The nerve-ring encircles the œsophagus pretty squarely. The tail is concave-conoid from the inconspicuous anus, and ends in an apiculate spinneret, one fourth as wide as the anal body-diameter is long. The vulva is rather conspicuous. The eggs are one and one half times as long as the body is wide, and two thirds as wide as long, and appear to be deposited before segmentation begins. The reflexed ovaries reach one half to two thirds the distance back to the vulva.

Habitat.—Found about the roots of moss near Maclean, Clarence River, New South Wales, Australia.

13. Cephalobus.

Some of the species of this genus have latterly come to be regarded with suspicion by those who pay particular attention to the diseases of plants. They are found to be in some cases parasitic or quasi-parasitic, and to occur in myriads, more especially in diseased parts. It remains, however, to be proved that they are the real offenders in such cases. From the structure of the mouth parts, one would expect the food to be such as to require little or

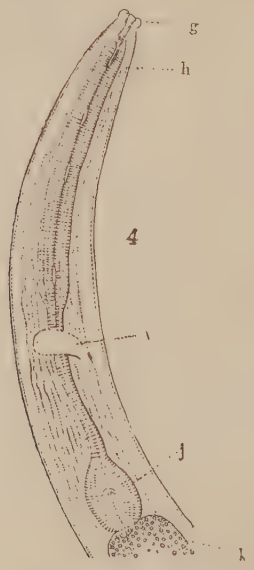


Fig. 43.—Head and neck of a *Cephalobus*, magnified. *g*, lips; *h*, base of the pharynx; *i*, nerve-ring; *j*, posterior sucking-bulb; *k*, intestine.

no mastication, resembling as they do those of the genus *Rhabditis*. Many species of *Rhabditis* live for the most part on fouling matter, which has been reduced to a liquid or semi-liquid state by the action of fungi and microbes. It may be that this is true of most *Cephalobi*, and that where they have been found in such numbers in diseased parts of plants, they have been preceded by other organisms, which are the primary cause of the disease. The reader will be assisted to understand the nature of the mouth-parts and œsophagus by consulting the accompanying cut, showing the head and neck of a species found among the sheaths of diseased banana plants from Fiji.

1. *Cephalobus multicinctus*, n. sp. $\frac{2{\cdot}1}{2{\cdot}3}$—$\frac{17{\cdot}}{4{\cdot}1}$—$\frac{27{\cdot}}{4{\cdot}5}$ $\frac{12{\cdot}}{4{\cdot}7}$ $\frac{35}{90{\cdot}}$ $\frac{}{2{\cdot}8}$ ·56 mm. The plain transverse striæ were easily resolvable with quarter-inch objectives, the distance between two successive striæ measuring two micromillimetres. There were no hairs on the body. The neck was convex-conoid anteriorily, and ended in a truncate head, devoid of setæ. The three inconspicuous lips were armed with

papillæ. Curved markings, somewhat hook-shaped, or like an unclosed figure six, and located on the sides of the head at a distance from the anterior extremity equal to the length of the posterior œsophageal bulb, seemed to represent the lateral organs. The shape of the pharynx is well shown in the adjacent wood-cut. The anterior two thirds of the œsophagus was about half as wide as the corresponding part of the neck. The junction of this part of the œsophagus, with the succeeding tubular part, was distinctly marked. There was no median swelling. About half-way down this anterior part of the œsophagus a sort of joint is indistinctly to be seen. The narrow tubular part of the œsophagus is only one fifth as wide as the neck, but expands at last to join the ellipsoidal cardiac bulb, which is two thirds as wide as the body.

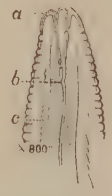


Fig. 44.—Head of *Cephalobus multicinctus*. *a*, the lips; *b*, base of the pharynx; *c*, œsophagus.

The intestine, which is separated from the œsophagus by a distinct constriction, was nearly three fourths as wide as the body, and presented a distinct lumen or channel. A small cardia projects into the large and conspicuous, thin-walled cardiac cavity. The rectum was twice as long as the anal body-diameter. The ventral excretory pore was located opposite the nerve-ring. This latter encircled the œsophagus a trifle obliquely, and was as wide as the anterior half of the œsophagus. The wings of the cuticle appeared as three longitudinal lines when seen under the microscope, the distance between the two outer lines being equal to one seventh the width of the body. The tail was conical from the inconspicuous anus, and contained no glands and had no spinneret. The vulva was inconspicuous—only slightly raised. There was but one ovary, and this extended first forward half way to the cardia, and then backward to a point equally far behind the vulva, where it was again reflexed and extended forward, and ended near the vulva. The ova were arranged single file. The eggs were as long as the body was wide, or a little longer, and nearly half as wide as long; they were segmented while still in the uterus.

Habitat.—About roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

14. Rhabditis.

This genus is one of great interest from a purely scientific point of view, but is of no great economic importance. It combines with many features of the free-living nematodes, a number of those of the sorts found parasitic in animals. The anatomy of a typical species is shown in the following illustrations:—

1. *Rhabditis simplex*, n. sp. $\frac{3{\cdot}3}{3\cdot}$ $\frac{15\cdot}{5{\cdot}4}$ $\frac{24\cdot}{6{\cdot}2}$ $\frac{'73\cdot}{5{\cdot}6}$ $\frac{88\cdot}{2{\cdot}7}$ '66 mm. This formula is derived from the measurements of two rather immature females. The cuticle was transversely striated. Neck conoid; head truncate; cephalic setæ wanting; lips six, well developed, each with a papilla; eyes lacking; pharynx prismoid, one fourth as wide as that part of the neck opposite its base, a trifle wider just at the lips; anterior part of the œsophagus about half as wide as the corresponding part of the neck; median

bulb an almost imperceptible swelling, located a trifle in front of the middle of the neck; tube connecting the median swelling with the posterior bulb one sixth as wide as the corresponding part of the neck; posterior bulb, ellipsoidal, half as wide as the base of the neck, and containing a distinct valve; intestine three fourths as wide as the body, its cells distinct, its lining thick, and its channel apparently sinuous; rectum more than twice as long as the anal body-diameter; excretory pore just behind the nerve-ring; nerve-ring oblique; tail conical; caudal glands absent; vulva conspicuous though not elevated; vagina conspicuous.

Habitat.—Virgin soil, hills opposite Harwood, Clarence River, New South Wales, Australia.

2. *R. minutus*, n. sp. $\frac{3{\cdot}7}{3{\cdot}1}$ $\frac{20}{5{\cdot}1}$ $\frac{33}{5{\cdot}2}$ $\frac{M}{5{\cdot}4}$ $\frac{93}{4}$ ·3 mm. Female unknown. The cuticle of this tiny worm is traversed by transverse striæ resolvable only with high powers. Like other species of *Rhabditis* the body is quite destitute of hairs. The neck is conoid, but becomes convex near the head, which is rather truncate, and bears no setæ, and only very inconspicuous papillæ—probably three. Neither lateral organs nor eyes were seen. The prismoid pharynx is one-fourth as wide as the anterior part of the neck, and is furnished near the lips with small separate pieces of chitine. The anterior part of the œsophagus is half as wide as the corresponding part of the neck, and ends in an elongated-ellipsoidal median bulb two-thirds as wide as the middle of the neck, where it is situated. The tube that leads onward from the median bulb is considerably narrower than the anterior part of the œsophagus, but expands finally to form an ellipsoidal bulb three-fourths as wide as the body. The valvular apparatus in this posterior bulb is distinctly to be seen. The intestine is three-fourths as wide as the body, its thin walls being lined with chitine. The cardia is very rudimentary, and the cavity behind it large and conspicuous. The ventral excretory pore is situated just behind the nerve-ring, which is as wide as the part of the œsophagus it obliquely encircles. The wings on the sides of the body are separated by a distance equal to one-eighth of the width of the body. The ventrally arcuate tail is conical from the elevated anus, and is completely enveloped by the bursa which springs from a point half as far in front of the anus as the middle of the tail is behind it. The terminus is pointed, and there are no caudal glands. The ribs of the bursa may be thus described:—There are eight pairs in all—two in front of the anus and very inconspicuous, four conspicuous long and slender ones on the anterior half of the tail, and three on the posterior third of the tail, less conspicuous. The two equal, brownish, linear, slightly arcuate spicula are axial in position, their proximal ends being inconspicuous. In length they are one and one half times greater than the anal body-diameter. The accessory pieces are half as long as the spicula;

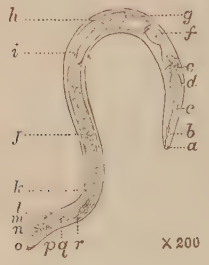


Fig. 45.—Male of *Rhabditis minutus*. *a*, lips; *b*, pharynx; *c*, œsophagus; *d*, median bulb; *e*, nervering; *f*, cardiac bulb; *g*, intestine; *h*, flexure in testicle; *i*, blind end of testicle; *j*, spermatozoa; *k*, ejaculatory duct; *l*, papilla; *m*, rib of bursa; *n*, ribs of bursa; *o*, ribs of bursa; *p*, accessory piece; *q*, left-hand spiculum; *r*, intestine.

instead of being placed parallel to the spicula they are placed nearly perpendicular to them. The testicle is so reflexed near its free extremity that the blind end lies as far behind the cardia as the latter is behind the mouth, the reflexed part being one-third as long as the neck. Most of these particulars are well illustrated in the adjacent figure.

Habitat.—Roots of sugar-cane, Harwood, Clarence River, New South Wales, Australia.

3. *R. filiformis* (?), *Bütschli* $\frac{2{\cdot}8}{2{\cdot}4}$ $\frac{14{\cdot}}{3{\cdot}8}$ $\frac{19{\cdot}}{4{\cdot}1}$ $\frac{'43'}{4{\cdot}3}$ $\frac{71{\cdot}}{2{\cdot}}$ ·5 to ·6 mm. This species is the same as that found in Fiji, and appears to be identical with that described by Professor Bütschli, under the name of *filiformis*. The following is a quotation from the description of this species as it stands in the *Macleay Memorial Volume*:—Cuticle plainly but finely transversely

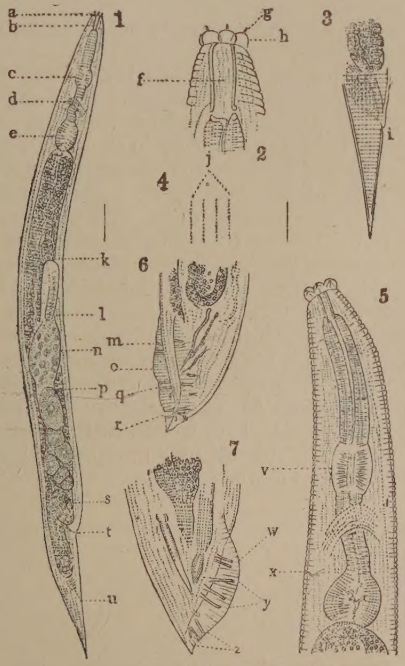


Fig. 46.—*Rhabditis filiformis:* 1, female worm magnified; 2, head of the same worm more highly magnified; 3, tail of the same worm; 4, figure to show relative width of body and lateral wings; 5, head and neck; 6, tail-end of a male; and 7, another view of the same

a, lips and papillæ
b, pharynx.
c, median œsophageal bulb.
d, nerve-ring.
e, posterior bulb.
f, pharynx.
g, papilla on lip.
h, lip.
i, anus.
j, wings of cuticle.
k, flexure in ovary.
l, blind end of ovary.
m, bursal ribs of anterior group.
n, spermatozoa.
o, bursa.
p, egg.
q, bursal ribs of median group.
r, ribs of posterior group.
s, segmented egg.
t, vulva.
u, anus.
v, median bulb.
w, ribs of anterior group.
x, excretory pore.
y, bursal ribs of median group.
z, bursal ribs of posterior group.

striated; neck nearly cylindrical to behind the pharynx, then convex-conoid to the mouth, which is one-fourth as wide as the base of the neck; lip

region half as wide as the prolate cardiac bulb; only traces of lips; no setæ or papillæ on the head; œsophagus in the anterior half fusiform and about half as wide as the neck, thence narrowing gradually to a tube one-fifth as wide as the neck; cardiac sucking bulb one-half as wide as the neck; cardiac collum distinct, the constriction deep; intestine thick-walled, four-fifths as wide as the body, with a thick transparent lining; cardia small, the cavity large; rectum narrow, nearly twice as long as the anal body-diameter, separated from the intestine by a distinct constriction; ventral excretory pore somewhat behind the middle of the neck (12·5 %); wings of the cuticle nearly as far apart as the opposite sides of the pharynx; tail conoid from the distinct anus, its terminus hair-fine; near the anus two lateral glands which empty through lateral pores at the beginning of the second sixth of the tail; vulva depressed; vagina very short; reflexed ovaries reaching half-way back to the vulva; eggs as long as the body is wide and two-thirds as wide as long.

Habitat.—Soil about roots of moss, &c., near Maclean, Clarence River, New South Wales, Australia.

The foregoing descriptions, comprise all that was learned about the nematode worms to be found on, or in, or about the roots of sugar-cane on the Clarence River. The conclusions to be drawn from my observations are briefly these: 1. Nematodes are abundant in the soil about the roots of cane both in healthy and diseased fields on the Clarence River. 2. They are not more abundant in badly diseased fields than elsewhere. 3. Most of the thirty species seen occur also in fields where no cane is growing, and many of them in virgin soil far removed from plantations. 4. While fully half the species seen are more or less injurious to plants, no species was seen in sufficient numbers to do a serious amount of damage, and not a single species was seen that appeared to be parasitic.

It is thought best to publish the descriptions, however, notwithstanding the negative results, and this for several reasons. They serve to show the detailed manner in which the investigations were conducted throughout, and serve to render it probable that Australian sugar-cane growers have little to fear from these baneful animals. They constitute furthermore, a considerable contribution to a scientific knowledge of a group of animals which includes many of the worst parasites known.

Sydney: Charles Potter, Government Printer.—1893.